Final Technical Report

Project title: **The Lamont Cooperative Seismographic Network and the Advanced National Seismic System: Earthquake Hazard Studies in the Northeastern United States.**

Network name: **Lamont-Doherty Cooperative Seismographic Network (LCSN)**

USGS Cooperative Agreement number: 07HQAG0021

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Term covered by this report: **February 1, 2007 – January 31, 2010 (3 years)**

Submitted on April 30, 2010

THE LAMONT COOPERATIVE SEISMOGRAPHIC NETWORK AND THE ADVANCED NATIONAL SEISMIC SYSTEM: EARTHQUAKE HAZARD STUDIES IN THE NORTHEASTERN UNITED STATES.

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Summary

The operation of the Lamont Cooperative Seismographic Network (LCSN) to monitor earthquakes in the northeastern United States is supported under this award. The goal is to compile a complete earthquake catalog for this region (ANSS-NorthEast) to assess the earthquake hazards correctly, and to understand the causes of the earthquakes in the region. The LCSN now operates 26 modern, broadband seismographic stations and 22 short-period analog stations in seven states: Connecticut, Delaware, Maryland, New Jersey, New York, Pennsylvania and Vermont. Six accelerographic stations are also deployed around metropolitan New York City as part of the ANSS urban ground motion network. During February 2007 through January 2010, scientists and staff at the Lamont-Doherty Earth Observatory of Columbia University (LDEO) satisfactorily carried out three main objectives of the project: 1) continued seismic monitoring for improved delineation and evaluation of hazards associated with earthquakes in the Northeastern United States, 2) improved real-time data exchange between regional networks and the USNSN for development of an Advanced National Seismic System (ANSS) and expanded earthquake reporting capabilities, and 3) promoted effective dissemination of earthquake data and information products.

A significant amount of associated research effort was related to rapid determination of seismic moment tensor and focal depth of small to moderate-sized earthquakes in the eastern United States by using three-component, broadband seismic waveform data. We implemented rapid generation of instrumental ground motion and intensity maps—ShakeMaps. For real-time data exchange, integration and archive, LCSN exceeds the "ANSS Performance Standard (APS) v2.4". For rapid generation of earthquake parameters, LCSN performs slightly under the target outlined in the category, Mod-High Hazard Area. In particular, hypocenter and magnitude are usually posted in 15 – 30 minutes. We are working towards ~5 minutes latency for accurate hypocenter and magnitude information. Moment tensor and ShakeMap have similar latency than the ANSS performance standard, and LCSN is trying to meet the APS target, that is, ~10 –15 minutes posting time.

The LCSN is unusual in using a variety of station operators (college & university faculty, secondary school teachers, museums, etc.) to engage a wide variety of audiences and to reach out to large numbers of the general public. It also provides professional development and improved awareness among station operators who are not professional seismologists. About half of the broadband station operators and stations belong to each participating organization. Hence, a large portion of the operation and maintenance cost are born by about 35 participating organizations.

Work performed during the 3-year award period.

1) New Stations

During the 3-year award period (Feb. 2007 – Jan. 2010), LCSN deployed seven new broadband seismographic stations in New York, New Jersey and Pennsylvania as listed below and plotted in Figure 1.

Station code	Lat. (°N)	Long. (°W)	Elev. (m)	Operation (year/mo/dy)	Station name	Cooperating institution
ODNJ	41.0829	74.6056	187	2007-06-23	Ogdensburg, NJ	Sterling Hill Mining Museum
WCNY	43.9810	75.6549	245	2007-06-27	West Carthage, NY	Carthage Central High School, NY
NPNY	41.7546	74.1435	216	2007-09-07	Mohonk Preserve, New Paltz, NY	SUNY-New Paltz
MSNJ	40.8841	74.1815	132	2007-11-02	Montclair State Univ., NJ	Rifle Camp Park, Montclair State U.
PANJ	40.3768	74.7028	100	2008-02-16	Princeton, NJ	Princeton Academy of the Sacred Heart
MMNY	42.7319	77.9066	241	2008-08-06	Mount Morris Dam, NY	USACE
KSPA	41.5570	75.7682	298	2009-07-09	Keystone College, PA	Keystone College, PA

LCSN also deployed ANSS urban strong-motion stations at Westchester Community College in Valhalla, NY (WCNY), East River Park, NYC; and Chelsea Waterside Park, NYC (CWP).

Station code	Lat. (°N)	Long. (°W)	Elev. (m)	Operation (year/mo/dy)	Station name	Cooperating institution
PAL	41.0056	73.9079	66	2003-08-20	Palisades, NY	LDEO
CPNY	40.7912	73.9600	27	2003-05-20	Central Park, New York City	Central Park Conservancy
FOR	40.8631	73.8856	24	2003-08-21	Fordham University, NYC	Fordham University, NY
ERP	40.7130	73.9769	10	2007-11-09	East River Park, Lower Mahattan, New York City	USGS Central Hazard Team, Golden, CO
MMNY	42.732	77.907	241	2008-08-06	Mount Morris Dam, NY	USACE
WCCN	41.0684	73.7914	144	2007-04-05	Westchester Comm. College, NY	Westchester Comm. College
CWP	40.7496	74.0072	23	2007-11-20	Chelsea Waterside Park, Manhattan	USGS, Golden, CO

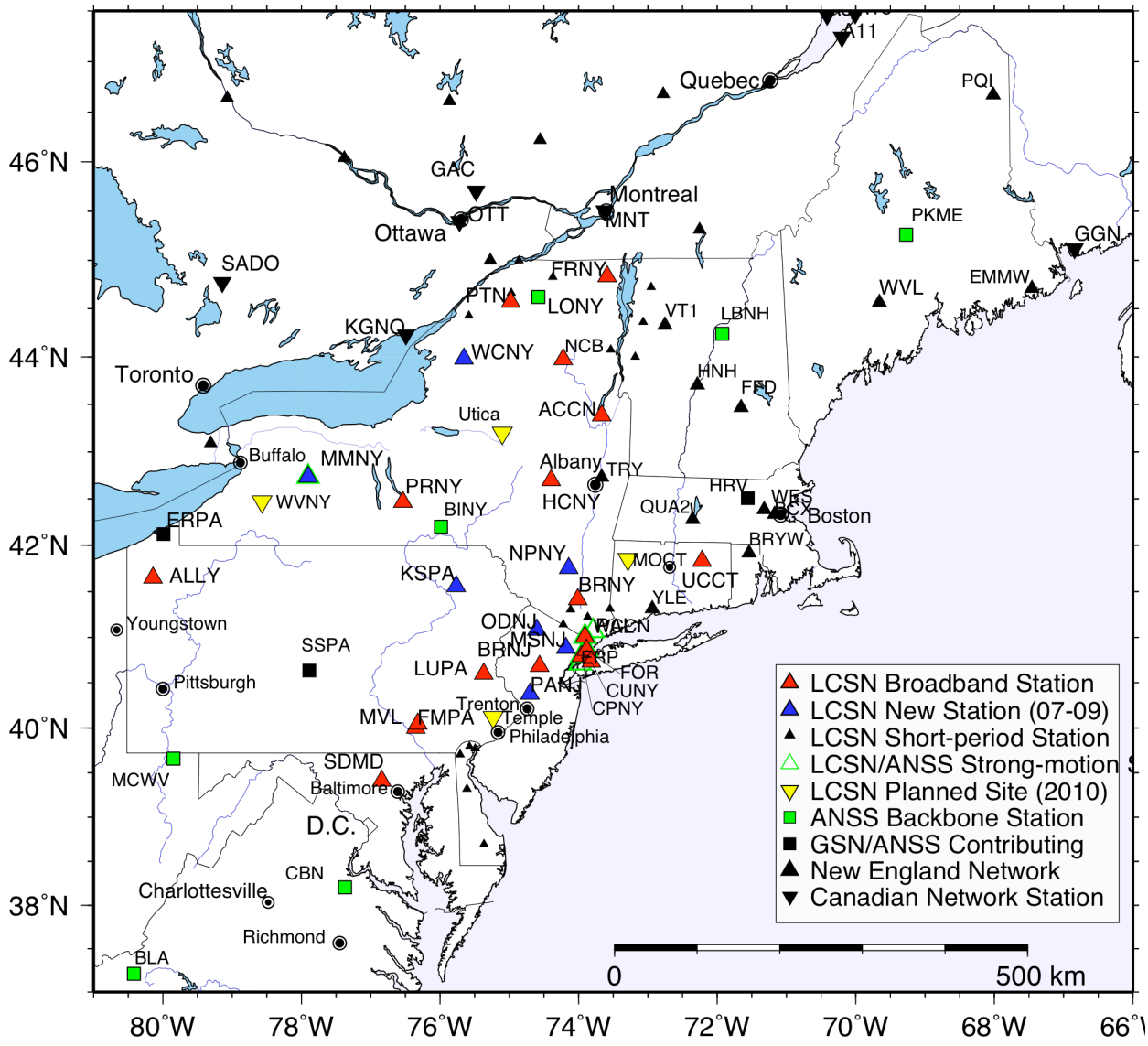

Figure 1. Map of seismographic stations of the LCSN and other networks in the northeastern U.S. Seven new broadband stations (*blue triangles*), 18 existing broadband (*red triangles*), 15 short-period (*small filled triangles*) and 5 ANSS urban strong-motion (*green triangles*) seismographic stations of the LCSN are plotted. Additional four sites planned for new broadband stations during FY10-11 are plotted with *yellow triangles*. TUPA (Temple University, Philadelphia, PA), WVNY (West Valley, NY; NYSERDA[New York State Energy Research & Development Authority]), MOCT (Mohawk State Park, Connecticut), and Utica, NY (Utica College, NY) are sites under development with various partners. List of stations is given at the LCSN website: http://www.ldeo.columbia.edu/LCSN/Station/station-table.html.

2) New Procedures

Event relocation - all events within our authoritative region (which includes part of Canada) located by GSC are now relocated by LCSN using combined network data.

Site noise characterization - all stations in the network are reviewed periodically to examine site noise to suggest future improvements.

Event notification pager - for events located within region, in addition to email, the system also sends a text message to the operator's cell phone.

SeisNetWatch - system sends email to notify when stations are down during off-hours. This has improved system recovery from temporary outages. New Quanterra and other dataloggers are added.

Event catalog and database - all new events added to user searchable catalog and database once located. Waveforms, record sections and phase data available for each event. Events in catalog back to 1970 can be plotted on a map.

Event waveform database – waveform data from all new events are added to user downloadable database once the events are located. Waveform data are available for each event in full SEED format data.

ShakeMap v3.5 installed - In September of 2009, we installed ShakeMap v3.5 on a PC running under Linux operating system. Most of the software installed, but it is not fully running. We plan to make it functional when the installation of AQMS (ANSS Quake Monitoring System) at Lamont is completed and fully functional during the spring of 2010. During the ShakeMap workshop held in UC Berkeley on Oct. 8-9, 2009, LCSN agreed to work with the ShakeMap group at NEIC in Golden, CO to generate future ShakeMaps at NEIC.

EIDS (Earthquake Information Distribution System) - In December of 2009, following the ANSS-wide migration from QDDS to EIDS, we installed the EIDS software and proceeded to test for about a month that EIDS and QDDS were receiving the same information. This testing included receiving data into a separate QDM/RecentEqs. With the EIDS test concluded, QDDS was shut down.

3) New Partnerships

The following 15 organizations added as new members of the LCSN during the 3-year award period (Feb. 2007 – Jan. 2010). These are two middle- and high-school (West Valley Central School, NY and Princeton Academy of the Sacred Heart, NJ); nature conservation organization (Mohonk Preserve; Rifle Camp Nature Center); 4-year universities (SUNY - New Paltz; Montclair State; Princeton; SUNY – Stony Brook; Temple; Keystone College); science education center (Liberty Science Center, NJ) and two state and federal agencies (NYSERDA

and U.S. Army Corps of Engineers). These organizations are partners of the LCSN who are associated with the seven broadband stations deployed during 2007 – 2009.

- Sterling Hill Mining Museum in Ogdensburg, New Jersey (ODNJ): Mineral and mine museum operating in the tunnels and surrounding buildings on the ground level of an old zinc mine (New Jersey Zinc, Inc.). The Lamont Geological Observatory operated a geophysical lab in the underground tunnels in the mine including long- and short-period seismographic stations, strain meters, and microbarographs. This is a historically important site for Geophysics and earthquake science in which a WWSSN station OGD was deployed in a tunnel about 550 m below sea level during 1960-1984. URL: <http://sterlinghillminingmuseum.org>, PI: Museum Curator Dr. Earl Verbeek.

- Mohonk Preserve, New Paltz, NY (NPNY): Located just 90 miles north of New York City, the Mohonk Preserve provides visitors access to over 6,500 acres in the Shawangunk Mountains – including cliffs, forests, fields, ponds, and streams – and to a network of over 100 miles of carriage roads and trails for hiking, running and cross-country skiing. It was established in 1963. The Mohonk Preserve was the first land trust established to protect the Shawangunk Ridge. It is also one of the oldest land conservation organizations in the Hudson Valley region. LCSN installed a broadband seismographic station in August 2007 in the Mohonk Preserve in collaboration with the preserve, ISTI, and SUNY-New Paltz. URL: <http://www.mohonkpreserve.org/>, PIs: Drs. John Tomson and Bob Huth.

- SUNY – New Paltz, NY (NPNY): State University of New York at New Paltz has a strong Earth Science program and the program hosts NPNY station providing the Internet access for the station. PI: Prof. Fred Vollmer.

- ISTI (Instrumental Software Technologies, Inc.) is a software development company that specializes in writing custom software for the geophysical research community. ISTI has an office very close to the seismographic station NPNY, and provides software help and occasional station maintenance service. PI: Paul Friberg.

- Nature Center, Passaic County Parks Department, NJ (MSNJ): Rifle Camp Park in West Paterson, NJ has a Nature Center and LCSN installed a broadband seismographic station near the nature center and sends the digital data to Montclair State University, NJ for local archiving and export to LCSN. URL: <http://www.passaiccountynj.org/ParksHistorical/Parks/riflecamppark.htm>

- Montclair State University, NJ (MSNJ): Digital data from Rifle Camp Park, West Paterson is telemetered to the Montclair State University campus for local archive and export to LCSN via the Internet. Montclair State University has a vibrant Earth and Environmental Science Department and the station MSNJ is associated with the department.

- Princeton Academy of the Sacred Heart (PANJ): This K-8 grade middle school provides a quiet site for a new broadband seismographic station. The digital data are exported to Department of Geology & Geophysics, Princeton University and to LCSN central processing site. PI: Ms. Kathy Humora (Science teacher).

- Princeton University, Department of Geology & Geophysics, NJ (PANJ): Scientists at Princeton University provide help to the Earth Science program at the Princeton Academy of the Sacred Heart as well as act as host of the new seismic station PANJ. PIs: Frederik Simons, Allan Rubin, Lincoln Hollister.

- US Army Corps of Engineers, Buffalo District (MMNY): Mount Morris Dam along the Genesee River in western New York provides the best site for a broadband seismographic station in its escape tunnel (Top Tunnel) near the visitor center. Contacts: Eugene Lenhart, Don Yule, Ray Lewis. We are working with Outreach personnel at the Dam to make seismic display using touchscreen monitor at the William Hoyt Visitor Center at the Dam.

- West Valley Central School, NY, in collaboration with NYSERDA, Hillary Bowen – Superintendant) the West Valley Central School is hosting a broadband seismographic station in its campus where there are well exposed bedrock outcrops and quiet. The project is funded by NYSERDA for July 2009 – August 2010 and we are awaiting instruments (Trillium 120PA seismometer and RT130-01/6 datalogger) purchased in Jan. 2010.

- NYSERDA (New York State Energy Research and Development Authority) office in West Valley, NY is in the process of providing funding to LCSN to install a new broadband seismographic station at a nearby high school in the West Valley region. It will be a useful facility for public outreach and education as well as much needed regional monitoring station in western New York. Contact: Paul Bembia.

- LSC (Liberty Science Center) in Jersey City, NJ. Working with staff at LSC to display real-time seismic data on their multi-screen display for teacher learning center. Principal contact: Dr. Joseph Amara, Ms. Molly Rosig (Science Educator).

- SUNY Stony Brook University, L.I., NY: Working with Mr. Ben Vitaly and Dr. Dan Davis, we are taking over operation of their old seismic station at Caumsett State Park in Lloyd Harbor, LI, NY.

- Temple University, Philadelphia, Pa. During Nov. 16-17, 2008, LCSN staff supported "kids jump" at the Temple University campus to celebrate 10th anniversary of its College of Science & Technology. Together with Franklin Institute in Philadelphia, kids at Duckrey Elementary participated for the jump. It was to promote earth science among inner city kids. Temple University purchased Trillium 120PA broadband seismometer for the activity and will install a permanent station near its Ambler Campus outside of Philadelphia as part of LCSN. PI: Dr. Jonathan Nyquist.

- Keystone College in La Plume, Pa. is the latest partner of LCSN. PI: Prof. Ian Saginor.

4) Major tasks accomplished

4.1 Earthquake Bulletin and Catalogs for Earthquake Hazard Evaluation

Over 330 local and regional earthquakes with magnitude greater than about 1.0 that have occurred in the northeastern United States and southern Canada were detected and located by the

LCSN during January 1, 2007 through January 31, 2010 (see Figure 2). These earthquakes range from magnitude (Mc) 0.3 to 3.9 and are listed in Table A3.

Notable earthquakes during the period are:

- Four earthquakes with magnitude between 1.8 and 3.1 occurred near the town of Berne, NY about 30 km west of Albany, NY during June 30 – July 24, 2007. These shocks were followed by much more active sequence in February 2009. We located 22 small events during February 17 through December 13, 2009. The events had magnitude between 1.0 and 3.1, and appeared to have occurred at focal depth around 10-15 km.

- About a dozen small earthquakes occurred about 15 km south of Middletown, NY during March 11 – 18, 2008. Although the shocks had magnitude range 0.3 to 2.4, intensity at the epicentral area reached to MMI IV due to their shallow focal depths (about 0.5 km) (see Table A3 & Figure 2).

- Starting from October 5, 2008, swarm of small earthquakes occurred around Dillsburg, York County, Pennsylvania. From October 2008 – December 31, 2008, there were about 20 shocks with magnitude between 0.8 and 2.1 were located by the permanent network stations. During October – December, 2008, hundreds of micro-earthquakes were felt by local residents in Dillsburg. It is a typical case of earthquake swarm with very shallow focal depths and occurrence of numerous micro-earthquakes (see Figure A8).

4.2 Aftershock Studies Using Portable Instrument and Other Seismological Studies

Bar Harbor, Maine/Acadia National Park aftershock survey - recorded and located over 300 events around Mt. Desert Island, Maine from October 2006-June 2007.

SPAC Experiment in Lower Manhattan, NYC with USGS team.

Seismic experiment employing SPAC (SPatial AutoCorrelation) method to determine subsurface S-wave velocity profile was successfully carried out at six sites in Lower Manhattan, NYC during Nov. 5-9, 2007, in collaboration with Central Earthquake Hazard team of USGS, Golden led by Dr. Art Frankel. Figure 3 shows the six sites of SPAC experiment: East River Park, Columbus Park, Tompkins Square Park, Avenue C & 7th Street, Chelsea Park and Chelsea Waterside Park.

Dillsburg, Pa. aftershock survey:

Recorded and located over 40 events around Dillsburg, York County, Pa from October 2008-December 2008. It is a typical case of earthquake swarm with very shallow focal depths and occurrence of numerous micro-earthquakes.

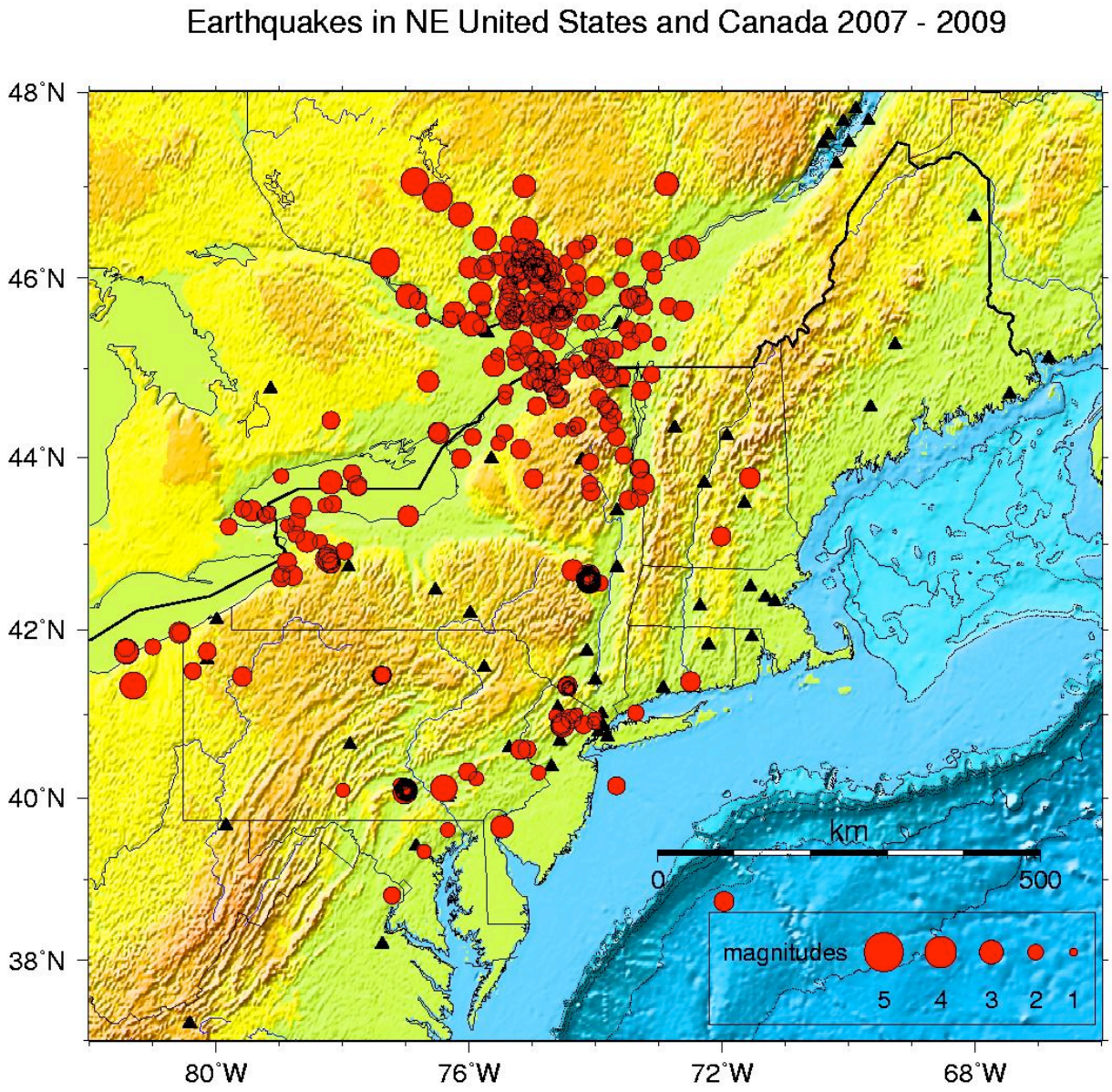

Figure 2. Earthquakes which have occurred in the northeastern United States and southeastern Canada in the time period of January 1, 2007 through January 31, 2010, recorded by the LCSN. Symbol size is proportional to magnitude. Broadband stations of the LCSN, USNSN, NESN, and CNSN are plotted for reference.

4.3 Other Technical Developments

LCSN Display – working with IRIS Active Earth Display, we developed LCSN Display that can be used by LCSN partners and participating institutions. http://www.iris.edu/activeearth/index.phtml?code=LCSN2007

Power improvements - PTN, LUPA - improved power backup and charging system due to older unreliable systems. Applying similar changes to other sites. Continuing to add UPS backup to PCs at each site.

New operating system testing - testing Linux version of earthworm at site ACCN and at Delaware Geological Survey subnetwork.

RF telemetry improvements:

We added 900MHz Ethernet bridges to site NPNY and 30 foot tall tower for RF telemetry was installed at PTN.

New digitizer testing:

We added Quanterra Q330 dataloggers at sites PAL, NPNY and PANJ. Eight Quanterra Q730 vintage datalogger from USNSN are being developed for new LCSN stations at DGS (Delaware Geological Survey) subnetwork.

New sensor testing:

We added Nanometrics Trillium 40T to site MSNJ and added Nanometrics Trillium 120PA to site at Keystone College, near Scranton, PA.

Earthquake Instrument Museum:

Opened a museum to show development of seismometers and seismographic networks in the 1950s through 1980s by Lamont scientists and engineers. Display includes Benioff short-period seismometer, Wood-Anderson torsion seismometer, Press-Ewing long-period seismometers, seismoscope, micro-barograph, and portable seismograph that use smoked paper.

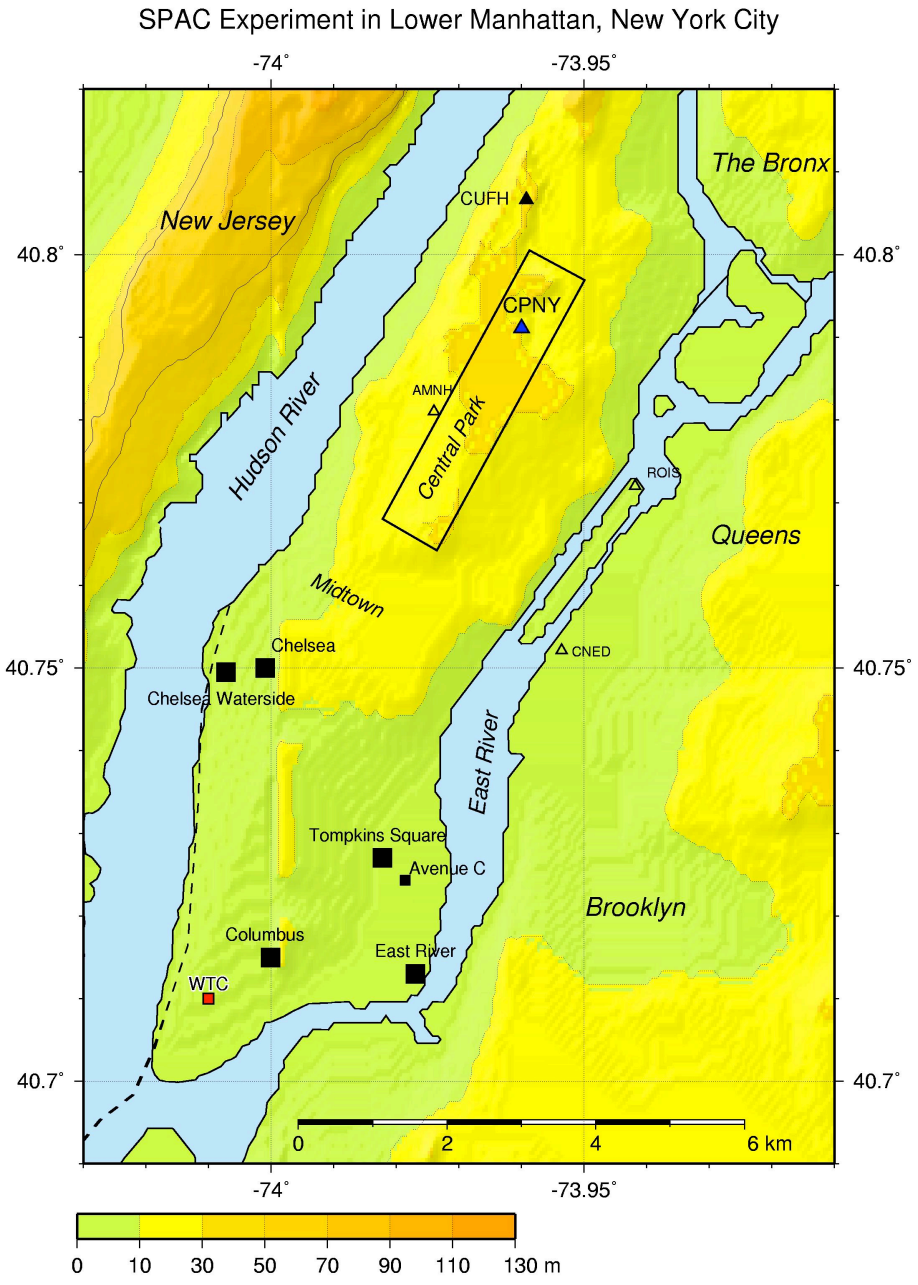

Figure 3. Map shows the six sites of SPAC experiment (*filled squares*): East River Park, Columbus Park, Tompkins Square Park, Avenue C & 7th Street, Chelsea Park and Chelsea Waterside Park. CPNY is an LCSN broadband seismographic station at Central Park, which also has ANSS CMG-5TD accelerograph recording continuously at 100 samples/s, and CUFH (Columbia University, Faculty House along Morning Side Drive) was the site of ANSS strong-motion station (CMG-5TD) that was closed due to building renovation. ROIS and CNED along East River are two temporary sites that we ran for aftershock survey in 2001.

Data Management Practices

Current state of progress toward meeting the ANSS data management performance standards 4.1 – 4.3 Data Exchange Between ANSS Networks, and 5.1 – 5.4 Data Archiving and Public Distribution are briefly described below for Mod-High Hazard Area.

Performance Area	Metric (explanations below)	Units	Mod-High Hazard Area (ANSS-NorthEastern US)
Data Exchange Between ANSS Networks			
4.1	Waveform Availability Timeliness	10 sec.	Real-time between NESN, CNSN, PRSN
4.2	Amplitude Availability Timeliness	60 sec.	Working to make real-time feed from New England Seismic Network for ANSS-NE ShakeMaps
4.3	Phase Picks Availability Timeliness	60 sec.	We are ready to import/export to ANSS Networks, ~60 sec
Data Archiving and Public Distribution			
5.1	Availability of Waveforms to External Users	0 min.	100 % Real-time via IRIS-DMC and LCSN AutoDRM http://almaty.ldgo.columbia.edu:8080/data.request.htm
5.2	Availability of Event Bulletin (parametric data)	15 min.	60 (we are meeting the goal via Finger Quake list) http://www.ldeo.columbia.edu/cgi-bin/quake.cgi
5.3	Metadata availability (current)	100 %	100 (downloadable via web site at http://www.ldeo.columbia.edu/LCSN/Metadata/DATALESS.LD.seed
5.4	Data import into archive	0 min.	100% in real-time (permanent archive at IRIS-DMC)

Continuity of Operations and Response Planning

1) Established a protocol to assign an ***event coordinator at LCSN*** who will establish contact with personnel at NEIC and maintain the contact throughout the processing, rapid response and assessment of earthquake effect. NEIC Event Coordinators (senior scientists) include

Harley Benz, Stuart Sipkin, Paul Earle, David Wald and Jim Dewey. Bill Leith is also considered as an event coordinator at Reston federal center for earthquakes in Washington DC area.

2) plans to respond to major earthquakes: We have a contingency plan to respond to major earthquakes in the eastern United States as listed in Attachment A. The plan includes aftershock monitoring fieldwork with portable seismographs (4 units are ready for the tasks), for earthquakes greater than M ~4 in the EUS, and M ~5 central and eastern US.

3) arrangements with other networks: we are exchanging waveform data and other products in near real-time with the following regional networks and talking to personnel at these institutions by phone and E-mail for earthquake response.
Weston Observatory, NESN (New England Seismic Network); Geological Survey of Canada, CNSN (Canadian National Seismic Network); NEIC/USGS (US National Seismographic Network); Puerto Rico Seismic Network (PRSN); Virginia Tech Seismic Observatory (VTSO); Southern Ontario Seismic Network (SOSN); Ohio Geological Survey.

4) plans to cope with power and communication failures: Computers and other components of the LCSN system are backed up by UPS and AC power from external generator. Main processing computer has dual power supply with 4 Terabyte RAID system to prevent failure. Data acquisition via the Internet can have communication failure and we have local archive at each local station. However, communication failure at the LCSN main site in the fall of 2007 led us to work with Columbia University main campus to replace and upgrade Internet routers at LDEO and at Columbia University.

Progress on Metadata Development

LCSN has nearly complete metadata for station characteristics and instrument responses since the early 1980s. Hence, event oriented SEED volumes were routinely generated and archived. Current, LCSN DATALESS SEED volume is available at IRIS-DMC and at the LCSN web page.

From LCSN home page at URL:
http://www.ldeo.columbia.edu/LCSN/Metadata/DATALESS.LD.seed
Click to download the file (5.3 Megabytes, 01/16/2009)

From Lamont-Doherty public ftp site:
ftp://ftp.ldeo.columbia.edu/archive/LCSN/DATALESS.LD.seed

From IRIS-DMC in Seattle, Wa.
ftp://ftp.iris.washington.edu/pub/dropoff/DATALESS.LD.seed

Since 2008, ANSS urban strong-motion instruments (CMG-5TD) with 100 samples/sec continuous and 200 samples/sec triggered system responses are included with location codes "(blank)" and "10" respectively, as well as new dataloggers such as Guralp DM-24/3 mk3.

Decimation filter blockette is added to the analog short-period stations to conform to SEED V2.4.

Table 1. Summary Statistics for Regional/Urban Seismic Network **(as of 31 Dec. 2009)**

Total no. of stations operated and/or recorded	48
Total no. of channels recorded	195
No. of short-period (SP) stations	22
No. of short-period (SP) stations with metadata	22
No. of broadband (BB) stations	26
No. of broadband (BB) stations with metadata	26
No. of strong-motion (SM) stations	6
No. of strong-motion (SM) stations with metadata	6
No. of stations maintained & operated by network	48
-same, with full metadata	48
No. of stations maintained & operated as part of ANSS	48
-same, with full metadata	48
Total data volume archived (mbytes/day)	1,500

Table 2. Earthquake Data and Information Products

Network Products		
Does the network provide the following?	Yes/No	Comments/Explanation
Primary EQ Parameters		
Picks	Yes	to regional networks, ANSS composite bulletin
Hypocenters	**Yes**	EIDS, QDM & Recent eqs, web, EMOs, Finger quake list
Magnitudes (& Amplitudes)	**Yes**	EIDS, QDDS, recent eqs, ANSS composite catalog, Finger quake list
Focal mechanisms	**Yes**	Usually for microearthquakes from portable network deployment
Moment Tensor(s)	Yes	Usually for events greater than Mw 3.5 on web, E-mail
Other EQ Parameters/Products		
ShakeMap	**Yes**	**Via Did-You-Feel-It? Web page**
Finite Fault	**No**	
Supplemental Information		
Felt Reports	**Yes**	Via Did-You-Feel-It? Web page http://pasadena.wr.usgs.gov/shake/ne/
Event Summary	Yes	Web page "Recent Earthquakes" and "Finger quake" http://www.ldeo.columbia.edu/cgi-bin/quake.cgi
Tectonic Summary	Yes	Web page "Recent Earthquakes" http://www.ldeo.columbia.edu/LCSN
Collated Maps		Web page "Recent Earthquakes" http://www.ldeo.columbia.edu/LCSN
Refined Hypocenters **(e.g. double-difference)**	Yes	Web page "Recent Earthquakes" http://www.ldeo.columbia.edu/LCSN
Web Content		
Recent EQ Maps	Yes	http://www.ldeo.columbia.edu/LCSN/recenteqs/

Network Products		
Station Helicorder	Yes	View Live Seismograms http://www.ldeo.columbia.edu/LCSN/view_pal.html
Station noise PDFs	Yes	IRIS-DMC QUACK (Quality Analysis Control Kit) http://www.iris.edu/servlet/quackquery/
Station Performance Metrics	Yes	Monthly & yearly on Operators workshop station up time (95%), data recovery (95%)
Network Description	Yes	LCSN web page on Stations/Network http://www.ldeo.columbia.edu/LCSN/Station/station.html
Station List	Yes	http://www.ldeo.columbia.edu/LCSN/Station/station-table.html
Station Metadata	Yes	ftp://ftp.ldeo.columbia.edu/archive/LCSN/DATALESS.LD.seed
Email Notification Services	Yes	To state OEMs, geological surveys, state police
Contact Info	Yes	http://www.ldeo.columbia.edu/LCSN/Contact/ http://www.ldeo.columbia.edu/LCSN/Station/station.html§
Region-specific FAQs	Yes	http://www.ldeo.columbia.edu/LCSN/eus.html
Region-specific EQ info	Yes	Earthquakes Eastern U.S. http://www.ldeo.columbia.edu/LCSN/eus.html
Waveforms		
Triggered	Yes	Finger Quake http://almaty.ldeo.columbia.edu:8080/eventwfdb.html and Event database http://www.ldeo.columbia.edu/cgi-bin/quake.cgi

Network Products		
Continuous	Yes	Data Access via AutoDRM at LCSN http://almaty.ldgo.columbia.edu:8080/data.request.htm IRIS-DMC (Archive & real-time) http://www.iris.edu/SeismiQuery/ http://www.iris.washington.edu/bud_stuff/dmc/
Processed	Yes	ANSS urban monitoring strong-motion data and Event waveform database http://almaty.ldeo.columbia.edu:8080/event
Summary Products		
Catalogs	Yes	Earthquakes in Eastern U.S. and Catalog Search http://almaty.ldeo.columbia.edu:8080/data.search.html
Metadata		
Instrument Response	Yes	Dataless Seed ftp://ft.ldeo.columbia.edu/archive/LCSN/DATALESS.LD.seed
Site Info (e.g. surface geology, Vs30)	Yes	Exist in ShakeMap generation, but need to be compiled for a simple display format.
Descriptions:		
Tectonic Summary: Text and/or figures describing the tectonic setting of the event and related activity		
Event Summary: Text and/or figures (press releases, collated media/disaster agencies info) that describes the earthquake and its effects		
Collated Maps: Any map or set of maps that illustrates the event properties, tectonics, hazards, etc		
Processed Waveforms: Specialized processing that is required by some portion of the community, e.g. processed strong motion records for the engineering community		
Catalogs: Lists of parameters that describe an earthquake(s) or information used to describe an earthquake (e.q., picks, locations, amps,..)		
Region-specific earthquake information: Description (text and/or maps) of historical earthquakes, faults/geology, etc.		

Additional Information, Comments, and Suggestions

In the following, we show several figures and photos that depict LCSN activities beyond tables and texts.

1) Status of LCSN broadband station uptime and data recovery percentage in 2008.

Target is over 90% uptime and data recovery rate across the network. Notice that uptimes are above 95% at most of the stations, except FOR, UCCT, PTN and CUNY.

Among the 24 broadband stations; 17 stations have uptime > 90%; 7 stations have uptime < 90% including two new stations – MMNY (Mt Morris Dam, NY) and PANJ (Princeton, NJ). Target is 95% uptime and data recovery at all stations.

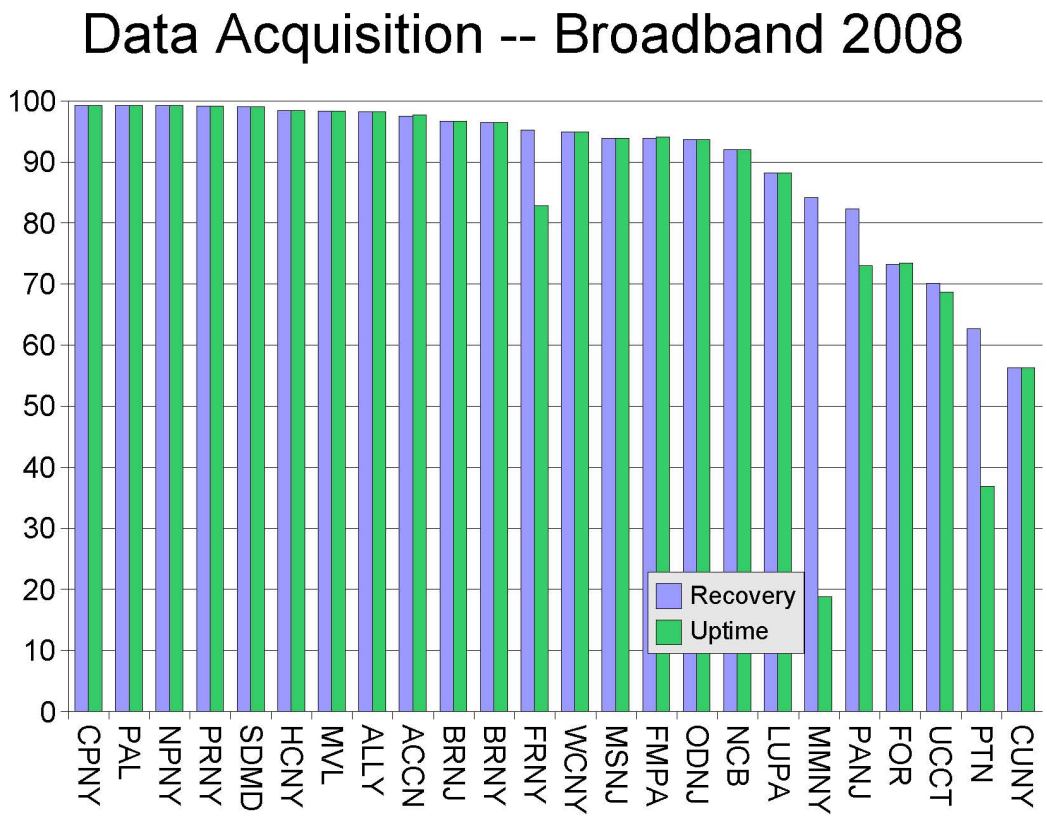

Figure A1. Histogram showing station uptime and data recovery percentage of LCSN broadband stations.

2) Quality of the waveform data is improving for many stations of the LCSN.

The global CMT (centroid moment tensor) project group at LDEO has evaluated quality of waveform data and associated metadata for several LCSN stations, and begun to use LCSN data on their routine analysis. The data analyses shown in Figures A2 and A3 indicate that data are in high quality and that its metadata are also correct. It is a good way to verify response function for a station.

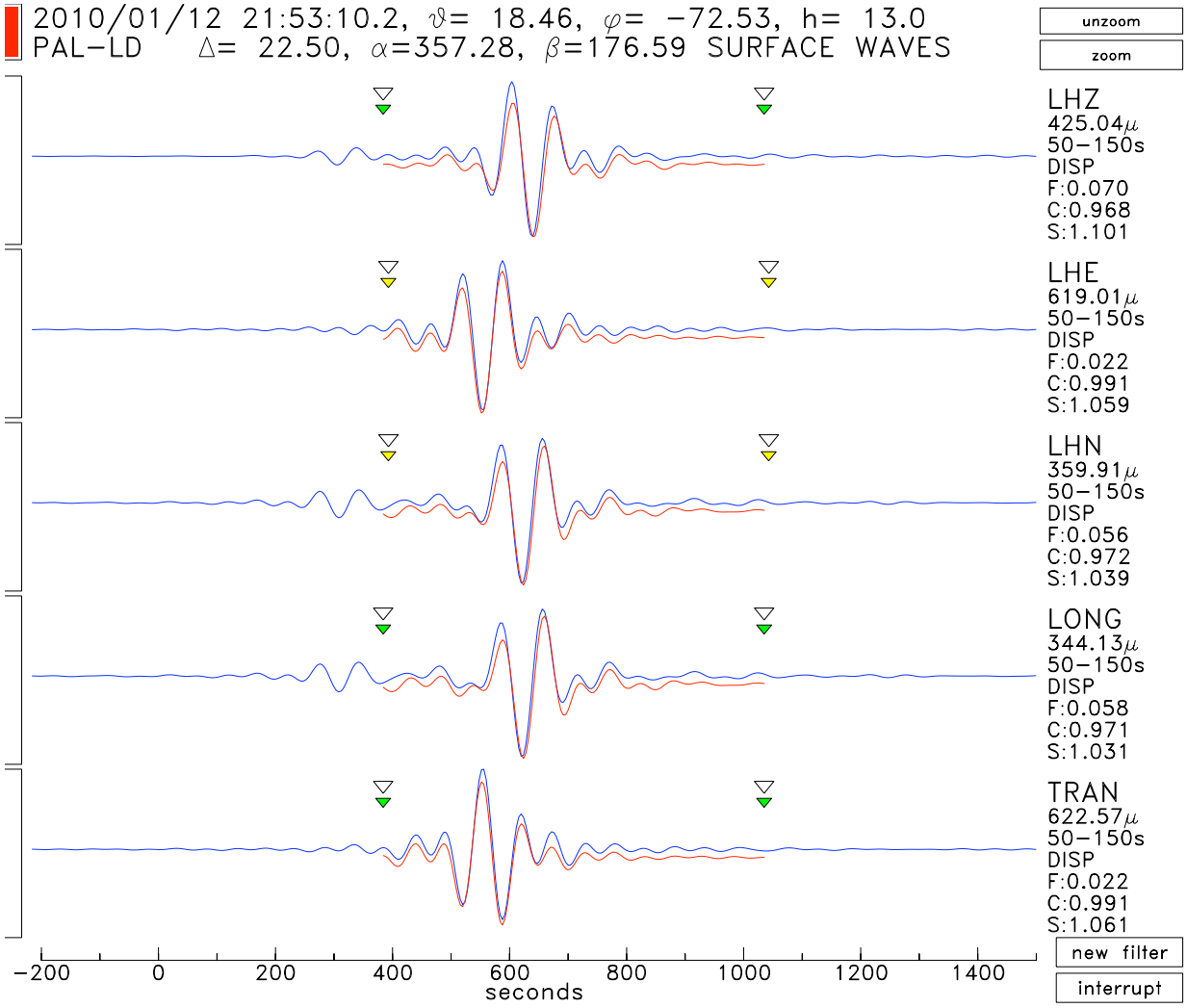

Figure A2. Surface-wave analysis of data from PAL (Palisades, NY) which has STS-2 seismometer (T_0=120s) and Quanterra Q330-HR datalogger. Signals are filtered between 50-150 s. It is a good way to verify response function for a station. The records are from the disastrous earthquake (magnitude 7) that occurred on January 12, 2010 in Haiti. (blue=data red=synthetics). [The figure courtesy of Meredith Nettles of LDEO].

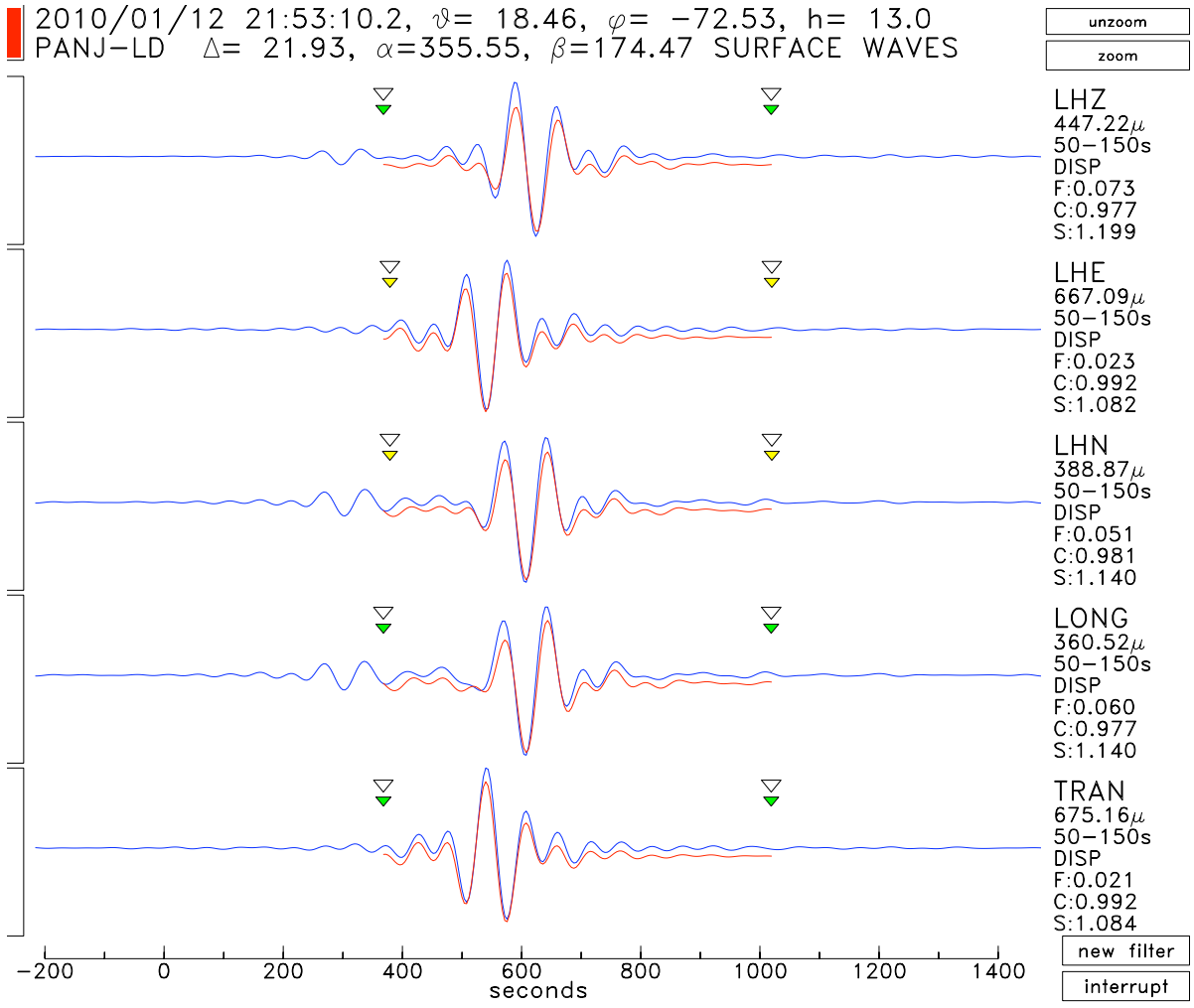

Figure A3. Surface-wave analysis of data from PANJ (Princeton, NJ) which has STS-2 seismometer (T_0=120s) and Quanterra Q330 datalogger. Signals are filtered between 50-150 s. It is a good way to verify response function for a station. The records are from the disastrous earthquake (magnitude 7) that occurred on January 12, 2010 in Haiti. (blue=data red=synthetics) [The figure courtesy of Meredith Nettles of LDEO].

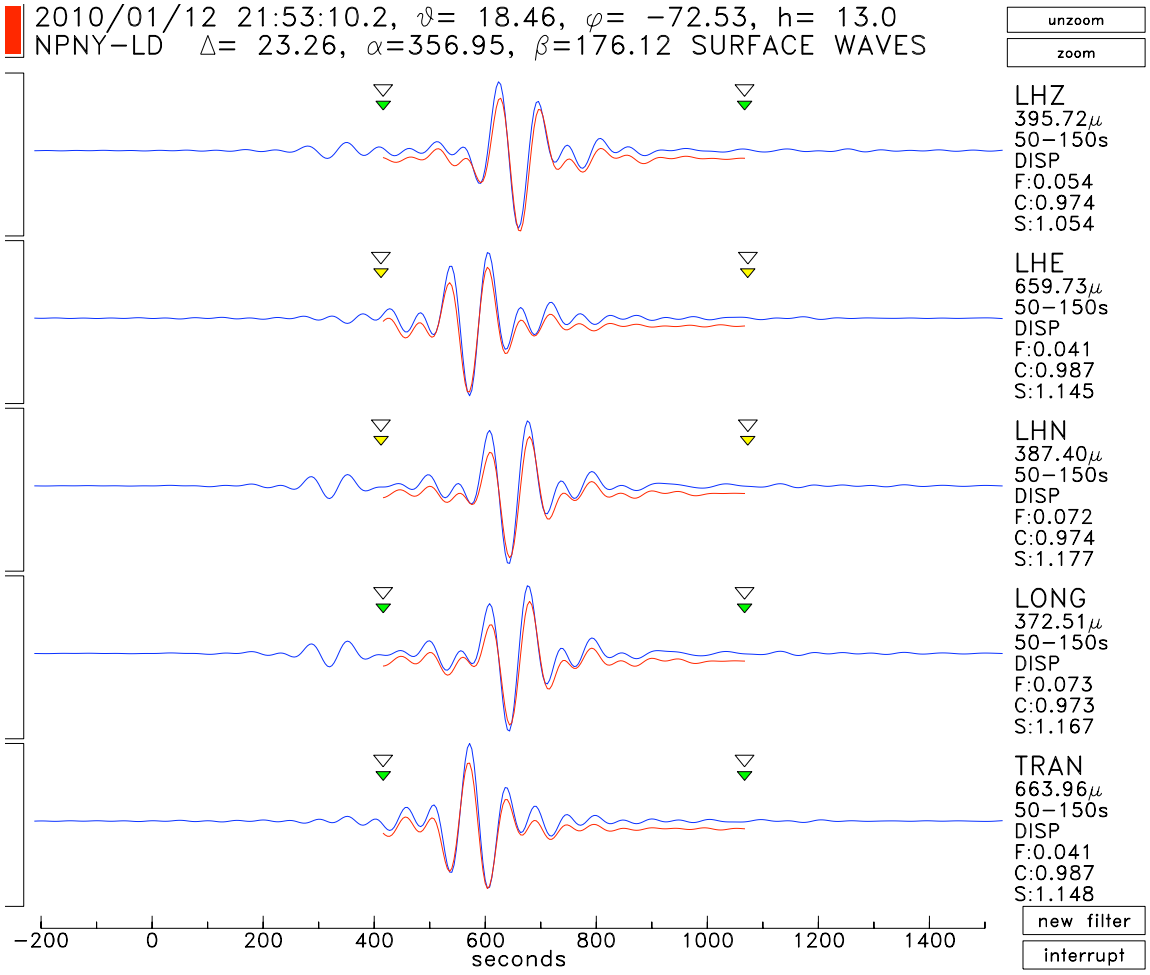

Figure A4. Surface-wave analysis of data from NPNY (New Paltz, NY) which has STS-2 seismometer (T_0=120s) and Quanterra Q330 datalogger. Signals are filtered between 50-150 s. It is a good way to verify response function for a station. The records are from the disastrous earthquake (magnitude 7) that occurred on January 12, 2010 in Haiti. (blue=data red=synthetics). [The figure courtesy of Meredith Nettles of LDEO].

3) Improved broadband station coverage in the Greater New York City region

Deployment of several broadband seismographic stations in and around New York City since 2007 has allows us to meet ANSS performance standard, such as ShakeMaps, regional moment tensor determination, and timely reporting. LCSN is planning to retire 35 years old short-period "legacy" seismographic stations in the greater New York City region in 2009.

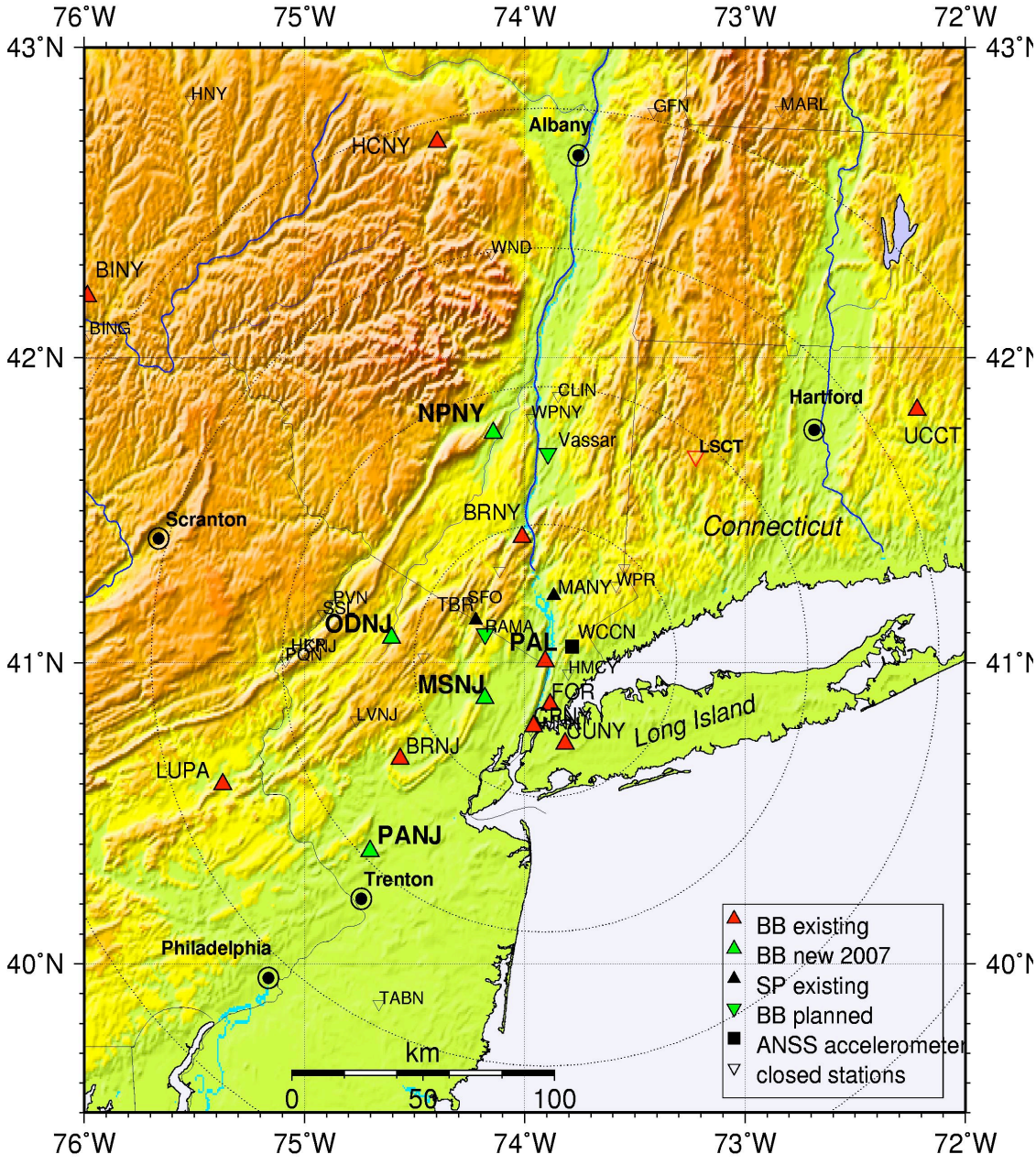

Figure A5. Improved broadband seismographic station coverage in the Greater New York City region that allows us to meet ANSS performance standard, such as ShakeMaps, regional moment tensor determination, and timely reporting. LCSN is planning to retire 35 years old short-period "legacy" seismographic stations at the beginning of 2010.

4) Relocating and upgrading LCSN stations in and around Rockland County, NY

We are working with the Rockland County emergency communication network to relocate three short-period stations and upgrading them into broadband stations. Notice that the relocation will improve monitoring earthquakes around Indian Point nuclear power plant in Buchanan, Westchester County.

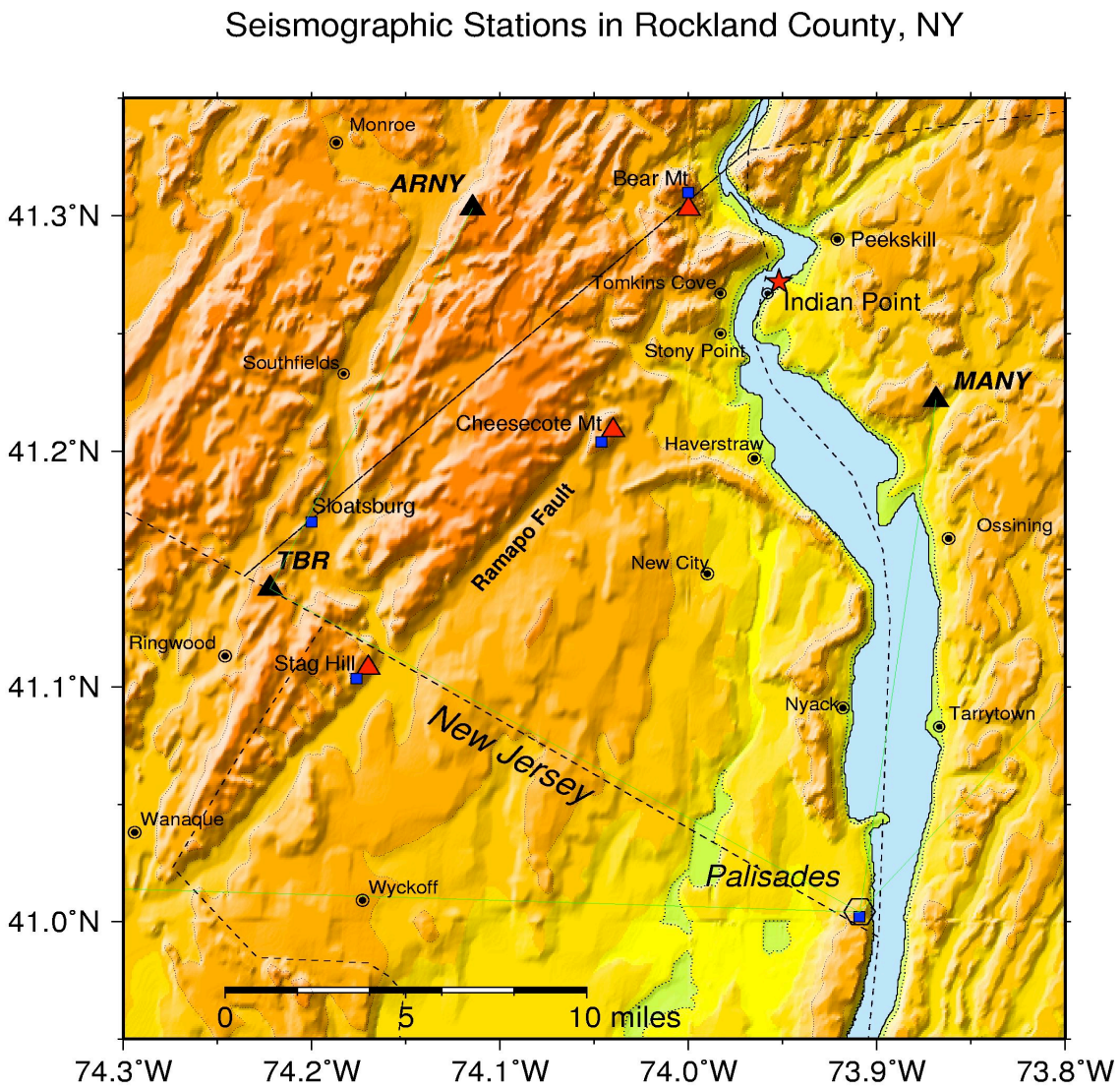

Figure A6. Seismographic stations in and around Rockland County, NY (*solid triangles*) and proposed Rockland County emergency communication microwave towers (*blue squares*). Current LCSN UHF and VHF radio telemetry links are indicated by *green lines*. New sites for seismic stations are plotted with *red triangles*: TBR may be relocated to Stag Hill, NJ; ARNY may be relocated to Bear Mountain; and MANY may be relocated to Cheesecote Mountain site. Seismic data from these three new stations can be transmitted to Lamont via the Rockland County's microwave communication network.

5) Ambient noise analysis of LCSN stations for station quality control

To evaluate quality of broadband seismographic stations power spectral density of ambient noise samples are carried out. Vertical acceleration power spectral density of stations equipped by sensors with T_0=100-120sec are plotted for comparison. Long-period portion of the ambient noise is very low at stations which have been upgraded to LCSN vault.

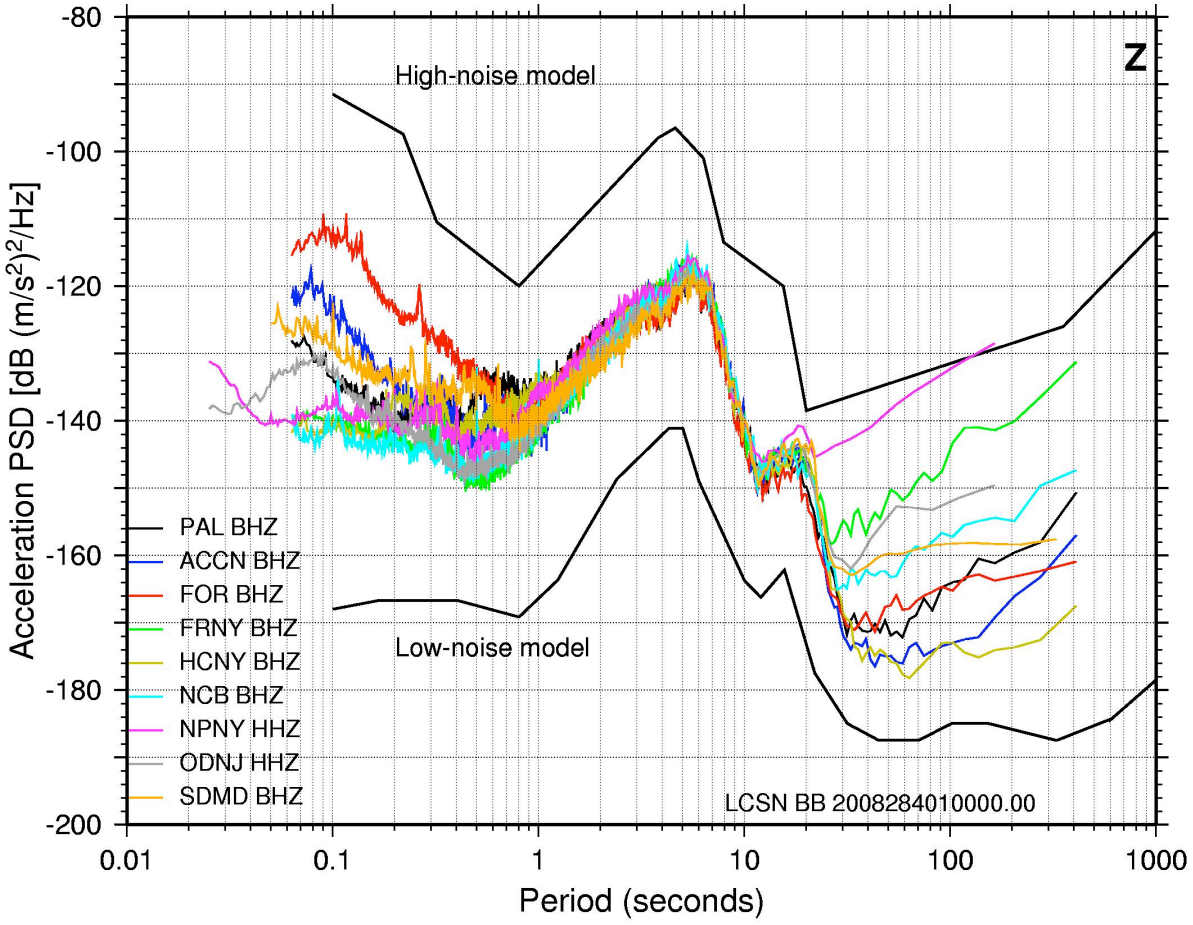

Figure A7. Acceleration power spectral density of vertical records from LCSN stations with broadband sensors having natural period, T_0 ≥100s.

6) Aftershock monitoring

Starting from Oct. 3, 2008, residents in Dillsburg, York County, Pennsylvania experienced ground shaking due to occurrence of small earthquakes. The largest event to date is M 2.1 event that occurred on Oct. 19, 2008. On Oct. 24th, LCSN deployed four station portable network in the epicentral area. During Oct. 24-Nov. 16, there were hundreds of micro-earthquakes. Among the numerous shocks, about 40 events are located and are plotted in Fig. A7.

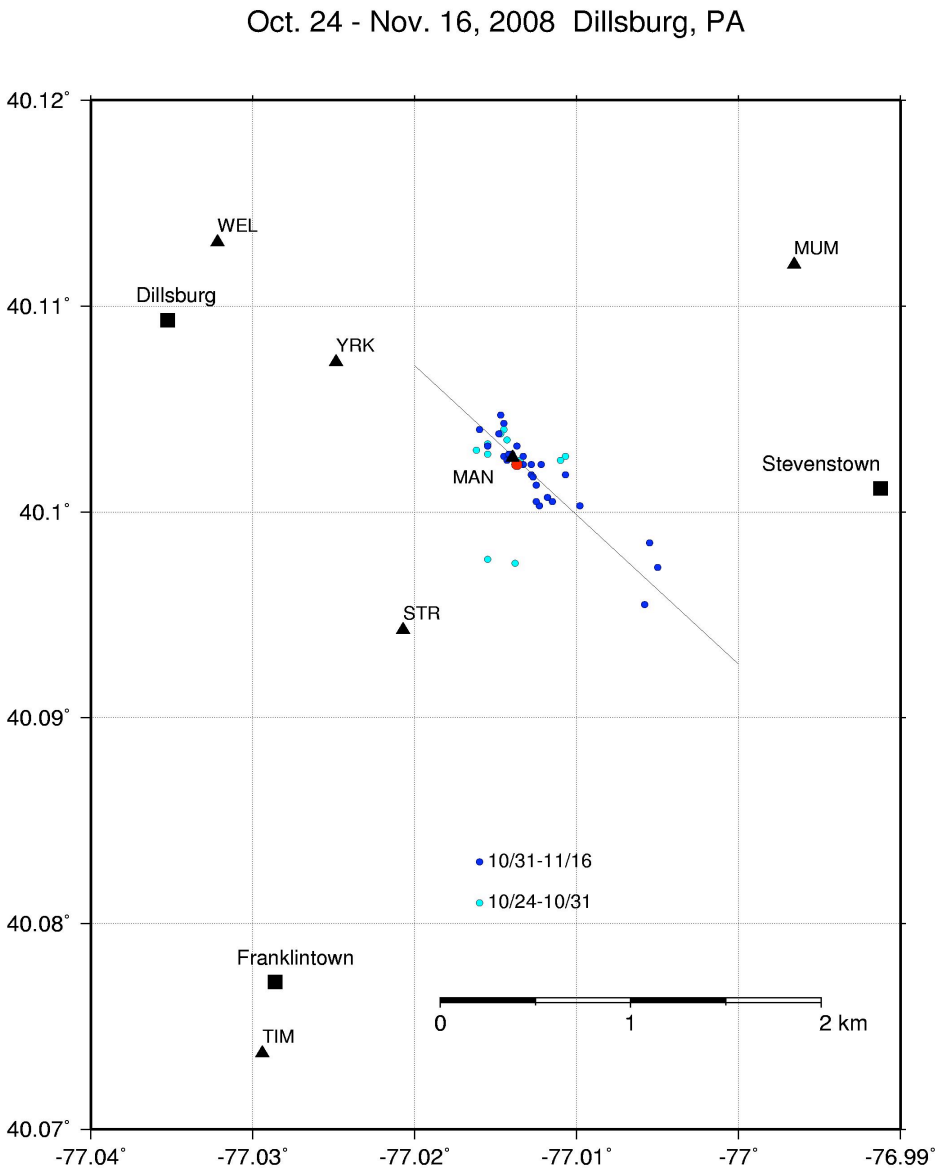

Figure A8. Epicenters of small earthquakes located by portable instrument. About 40 events during Oct. 24 – Nov. 16, 2008 are plotted. The largest event (M 1.4) during this period is indicated by a *red circle*. This event is also recorded by permanent stations, and hence can be used to relocate earlier events.

Appendix/Tables

Table A1: List of LCSN Broadband Stations Supported with USGS/ANSS Funds

Station code	Lat. (°N)	Long. (°W)	Elev (m)	Type	Open (yearmoda)	Network	Location (state)
ACCN	43.380	73.670	340	bb	19991109	LD	NY
ALLY	41.650	80.140	390	bb	20020530	LD	PA
BRNJ	40.680	74.570	50	bb	19991121	LD	NJ
BRNY	41.414	74.012	282	bb	20060622	LD	NY
CPNY	40.790	73.960	27	bb/sm	20020221	LD	NY
CUNY	40.730	73.820	20	bb	20020523	LD	NY
FMPA	40.048	76.321	121	bb	20050222	LD	PA
FOR	40.860	73.890	24	bb/sm	20020418	LD	NY
FRNY	44.840	73.590	223	bb	20031113	LD	NY
HCNY	42.697	74.398	273	bb	20060228	LD	NY
KSPA	41.557	75.768	298	bb	2009-07-09	LD	PA
LSCT	41.680	73.220	318	bb	19930806	US	CT
LUPA	40.600	75.370	236	bb	20010101	LD	PA
MMNY	42.734	77.906	241	bb/sm	2008-05-01	LD	NY
MSNJ	40.884	74.182	132	bb	2007-11-02	LD	NJ
MVL	40.000	76.350	91	bb	20010215	LD	PA
NCB	43.970	74.220	575	bb	19920101	US	NY
NPNY	41.755	74.144	216	bb	2007-09-07	LD	NY
ODNJ	41.083	74.606	187	bb	2007-06-23	LD	NJ
PAL	41.010	73.910	66	bb/sm	19991104	LD	NY
PANJ	40.377	74.703	100	bb	2008-02-15	LD	NJ
PRNY	42.467	76.536	205	bb	20060330	LD	NY
PTN	44.570	74.982	197	bb	20051028	LD	NY
SDMD	39.410	76.840	213	bb	20011101	LD	MD
UCCT	41.794	72.226	223	bb	20050113	LD	CT
WCCN	41.068	73.791	144	sm	20060518	LD	NY
WCNY	43.981	75.655	245	bb	2007-06-27	LD	NY

* Type: bb= 3-component broadband, sm= strong-motion instrument; Open= Station opening date; Network: LD= Lamont Cooperative Seismographic Network, US= US National Seismic Network.

Table A2: List of LCSN Short-period Stations Supported with USGS/ANSS Funds

Station code	Lat. (°N)	Long. (°W)	Elev (m)	Type	Open (yearmoda)	Network	Location (state)
ARNY	41.303	74.115	430	EHZ	19931216	LD	NY
BGR	44.829	74.374	297	EHZ	19761101	LD	NY
BRCN	44.428	75.583	83	EHZ	19761101	LD	NY
BVD	39.775	75.499	58	EHZ	19850201	LD	DE
BWD	39.800	75.577	63	EHZ	19850201	LD	DE
CHIP	44.798	75.195	97	EHZ	19940701	LD	NY
CRNY	41.312	73.548	293	EHZ	19811201	LD	NY
DEMA	39.319	75.610	12	EHZ	19991001	LD	DE
FINE	44.265	75.167	354	EHZ	19971001	LD	NY
FLET	44.723	72.952	366	EHZ	19770801	LD	VT
GPD	41.018	74.461	360	EH3	19760801	LD	NJ
HBVT	44.362	73.065	342	EHZ	19800901	LD	VT
MANY	41.222	73.869	133	EHZ	19931208	LD	NY
LOZ	44.620	74.580	440	EHZ	19991119	LD	NY
MDV	43.999	73.181	134	EHZ	19700301	LD	VT
MIV	44.075	73.534	317	EHZ	19841001	LD	NY
MSNY	44.998	74.862	55	EHZ	19761101	LD	NY
NED	39.704	75.705	47	EHZ	19721101	LD	DE
PNZ	44.835	73.577	215	EHZ	19961022	LD	NY
POTS	41.41	74.01	248	EH3	20060616	LD	NY
SCOM	38.696	75.363	12	EHZ	19991001	LD	DE
TBR	41.142	74.222	261	EHZ	19750101	LD	NY

* Type: EHZ= short-period vertical-component; EH3= 3-component, short-period station; Open= Station opening date; Network: LD= Lamont Cooperative Seismographic Network.

Table A3: Earthquakes recorded by LCSN for period January 1, 2007 through January 31, 2010[6]

Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2007						
2007-01-03	09:08:30.6	41.746	80.145	1	2.1	41 km W of Titusville, PA
2007-01-14	10:02:38.0	43.985	76.128	3	2.3	17 km W of Watertown, NY
2007-01-15	10:19:27.2	45.512	74.177	10	1.8	20 km SE of Lachutte, QUE
2007-01-19	03:56:54.0	44.417	78.189	6	2.1	127 km NE of Toronto, ONT
2007-01-20	17:20:00.8	42.637	78.796	8	2.4	21 km SW of East Aurora, NY
2007-01-26	08:58:11.8	46.099	75.150	7	2.6	39 km N of Ripon, QUE
2007-01-26	15:01:56.1	46.094	74.674	16	1.5	51 km NE of Ripon, QUE
2007-01-26	17:25:03.8	46.148	75.743	7	2.2	30 km SE of Maniwaki, QUE
2007-01-27	07:52:43.4	45.781	73.489	11	2.2	28 km S of Joliette, QUE
2007-01-27	17:49:45.7	45.031	74.044	7	2.3	26 km S of Valleyfield, QUE
2007-01-28	09:30:41.1	45.693	72.855	7	2.0	10 km NE of St. Hyacinthe, QUE
2007-01-29	05:06:50.5	44.578	74.934	1	2.2	11 km S of Potsdam, NY
2007-01-30	02:47:52.6	45.559	74.555	10	2.9	19 km SW of Lachutte, QUE
2007-01-30	10:40:16.6	45.922	74.897	8	2.3	26 km NE of Ripon, QUE
2007-02-01	01:04:41.5	43.870	73.316	5	2.2	20 km SW of Middlebury, VT
2007-02-03	02:21:14.7	45.958	74.619	7	1.8	40 km N of Hawkesbury, ONT
2007-02-03	06:10:16.0	45.559	74.550	9	2.0	19 km SW of Lachutte, QUE
2007-02-07	23:23:11.3	45.916	75.368	7	1.7	27 km NW of Ripon, QUE
2007-02-14	07:47:30.9	45.963	75.322	7	1.0	29 km NW of Ripon, QUE
2007-02-17	05:03:35.0	45.543	75.335	7	2.1	29 km SW of Ripon, QUE
2007-02-27	16:46:58.9	45.068	75.257	15	2.0	33 km NW of Massena, NY
2007-03-05	00:33:05.2	45.628	75.233	13	2.7	16 km SW of Ripon, QUE
2007-03-11	02:33:13.2	44.954	73.840	7	2.5	38 km E of Malone, NY
2007-03-12	23:18:18.7	41.344	81.312	2	3.5	35 km NE of Akron, OH
2007-03-16	02:05:12.7	45.753	76.812	8	2.1	95 km NW of Ottawa, ONT
2007-03-21	15:55:38.1	43.762	71.565	6	2.6	27 km N of Laconia, NH
2007-03-24	16:51:16.7	46.309	72.666	5	2.8	9 km SW of Trois Rivieres, QUE
2007-03-26	16:49:15.6	42.546	73.938	0	1.8	19 km SW of Albany, NY*
2007-03-27	00:51:09.4	46.068	74.825	7	1.4	42 km NE of Ripon, QUE
2007-04-01	05:48:47.1	45.207	73.704	7	2.0	23 km W of Napierville, QUE
2007-04-05	22:51:05.3	43.657	77.749	8	1.9	50 km N of Greece, NY
2007-04-06	04:00:56.4	43.674	77.773	7	2.4	52 km N of Greece, NY
2007-04-09	05:12:17.9	45.663	75.779	7	1.6	28 km N of Ottawa, ONT
2007-04-10	10:05:10.5	46.113	75.996	9	2.7	41 km N of Ripon, QUE
2007-04-11	02:32:17.4	43.325	76.966	7	2.6	33 km N of Newark, NY
2007-04-12	00:22:58.4	45.642	75.784	5	1.6	26 km N of Ottawa, ONT

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2007-04-12	00:58:14.8	45.593	74.927	18	1.5	8 km S of Montebello, QUE
2007-04-13	01:27:51.0	46.112	74.890	12	1.9	44 km NE of Ripon, QUE
2007-04-15	03:56:25.0	46.101	75.291	7	2.0	41 km N of Ripon, QUE
2007-04-15	12:59:08.1	43.603	74.075	8	2.2	46 km NW of West Glens Falls, NY
2007-04-20	01:42:11.9	40.230	75.892	7	1.6	13 km SE of Wyomissing, PA
2007-04-21	17:34:26.5	47.003	75.133	5	2.9	58 km NE of Mont Laurier, QUE
2007-04-26	16:15:05.7	40.983	74.639	0	1.3	11 km NW of Wharton, NJ*
2007-04-26	17:15:55.2	40.999	74.308	0	1.3	16 km NW of Fair Lawn, NJ*
2007-04-28	12:55:43.0	46.324	74.924	8	1.5	52 km SE of Mont Laurier, QUE
2007-05-02	10:50:48.3	44.663	74.614	10	2.4	29 km E of Potsdam, NY
2007-05-04	09:22:20.2	44.156	75.536	6	1.7	36 km NE of Watertown, NY
2007-05-07	00:59:57.0	45.301	74.620	11	1.9	34 km S of Hawkesbury, ONT
2007-05-11	05:55:22.9	46.692	76.138	17	3.2	38 km N of Maniwaki, QUE
2007-05-14	08:10:30.4	43.697	73.248	8	2.8	24 km NW of Rutland, VT
2007-05-15	04:19:54.2	40.311	76.029	7	2.1	6 km W of Wyomissing, PA
2007-05-16	09:16:19.9	45.649	74.500	15	2.1	12 km W of Lachutte, QUE
2007-05-21	10:21:45.2	45.987	74.737	7	1.3	39 km NE of Montebello, QUE
2007-05-21	10:22:25.0	45.983	74.724	7	1.9	39 km NE of Montebello, QUE
2007-05-21	10:24:10.2	45.985	74.742	7	1.3	38 km NE of Montebello, QUE
2007-05-23	02:14:00.9	45.538	76.734	7	1.5	82 km W of Ottawa, ONT
2007-05-27	05:28:21.0	44.231	73.676	7	2.2	38 km E of Saranac Lake, NY
2007-05-31	01:57:44.1	47.025	72.882	4	3.0	46 km S of La Tuque, QUE
2007-06-02	02:19:54.5	46.091	74.957	15	3.0	40 km N of Ripon, QUE
2007-06-04	12:33:30.3	42.608	78.980	6	2.2	27 km SW of Lackawanna, NY
2007-06-04	22:56:48.6	43.334	79.259	8	1.3	31 km NW of Niagara Falls, NY
2007-06-08	04:32:56.4	44.751	73.283	9	2.3	15 km NE of Plattsburgh, NY
2007-06-25	11:17:30.3	46.331	74.946	18	1.8	50 km SE of Mont Laurier, QUE
2007-06-26	06:37:30.4	45.587	75.340	10	1.1	25 km SW of Ripon, QUE
2007-06-28	06:18:09.3	40.876	74.194	2	2.1	9 km SW of Fair Lawn, NJ
2007-06-30	02:20:03.3	42.583	74.142	18	2.1	25 km SW of Westmere, NY
2007-07-01	03:12:55.1	42.562	74.137	15	1.4	26 km W of Delmar, NY
2007-07-02	06:02:44.6	43.091	72.021	7	2.3	27 km NE of Keene, NH
2007-07-02	07:06:21.9	45.235	74.112	8	1.3	3 km SE of Valleyfield, QUE
2007-07-08	11:43:40.5	42.792	78.882	7	2.3	6 km SW of Lackawanna, NY
2007-07-19	17:07:58.2	43.714	78.194	5	3.0	57 km N of Medina, NY
2007-07-21	03:56:28.5	44.538	73.794	7	2.2	33 km SW of Plattsburgh, NY
2007-07-24	00:48:57.2	42.600	74.120	14	2.6	23 km SW of Westmere, NY
2007-07-24	01:56:48.7	42.604	74.119	15	3.1	23 km SW of Westmere, NY
2007-07-25	11:33:22.6	43.369	79.157	5	1.3	32 km N of Niagara Falls, NY

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2007-07-28	08:07:17.6	45.175	75.306	7	1.6	41 km SE of Ottawa, ONT
2007-07-31	03:04:44.0	44.542	73.790	7	2.2	32 km SW of Plattsburgh, NY
2007-08-09	07:21:00.2	45.646	74.393	10	1.2	3 km W of Lachutte, QUE
2007-08-10	13:04:52.2	45.072	74.317	8	1.5	25 km SW of Valleyfield, QU
2007-08-11	07:31:19.9	44.271	76.478	4	2.6	56 km NW of Watertown, NY
2007-08-16	06:53:06.4	46.212	75.577	8	1.4	35 km SE of Maniwaki, QUE
2007-08-18	10:28:04.3	44.272	75.441	4	2.0	42 km SW of Canton, NY
2007-08-22	21:31:23.9	46.079	75.235	10	2.6	38 km N of Ripon, QUE
2007-08-30	03:47:45.7	44.323	74.360	2	0.0	18 km W of Saranac Lake, NY
2007-09-01	00:21:47.4	43.337	79.210	1	2.0	30 km NW of Niagara Falls, NY
2007-09-09	07:17:46.4	44.784	74.678	9	2.1	23 km SE of Massena, NY
2007-09-12	11:01:28.6	45.633	75.132	9	2.7	13 km S of Ripon, QUE
2007-09-15	05:56:44.3	44.321	74.354	5	1.7	18 km W of Saranac Lake, NY
2007-09-18	03:04:39.0	44.854	76.652	7	2.7	94 km W of Ogdensburg, NY
2007-09-18	06:22:59.6	45.750	75.234	14	1.6	9 km W of Ripon, QUE
2007-09-22	14:04:48.7	43.030	78.363	6	1.6	15 km W of Batavia, NY
2007-09-25	02:38:12.7	46.167	75.061	10	1.8	47 km N of Ripon, QUE
2007-09-28	08:46:05.9	41.969	80.579	7	2.7	19 km NE of Ashtabula, OH
2007-09-28	15:05:18.6	41.969	80.567	8	2.1	20 km NE of Ashtabula, OH
2007-09-30	17:35:35.6	46.882	76.504	8	3.9	71 km NW of Maniwaki, QUE
2007-10-01	02:11:54.8	43.448	78.281	7	1.6	27 km N of Medina, NY
2007-10-01	05:08:24.7	46.019	73.075	7	1.7	4 km SE of Sorel, QUE
2007-10-01	16:42:09.3	47.046	76.864	12	3.7	102 km NW of Maniwaki, QUE
2007-10-05	12:48:54.8	40.895	74.033	8	1.3	10 km SE of Fair Lawn, NJ
2007-10-08	12:28:02.0	39.343	76.714	8	1.5	11 km NW of Baltimore, MD
2007-10-09	07:42:21.2	46.351	74.160	11	1.4	64 km N of St-Jerome, QUE
2007-10-10	15:58:33.4	45.804	73.346	9	2.5	27 km S of Joliette, QUE
2007-10-10	16:02:58.6	45.807	73.325	13	1.7	27 km S of Joliette, QUE
2007-10-12	09:27:30.0	44.305	74.549	7	1.5	33 km W of Saranac Lake, NY
2007-10-13	05:53:31.9	46.525	75.129	11	3.5	30 km E of Mont Laurier, QUE
2007-10-17	16:17:22.6	44.989	73.918	12	1.9	34 km NE of Malone, NY
2007-10-17	20:04:10.2	41.749	81.420	3	3.1	15 km W of Painesville, OH
2007-10-29	22:04:46.6	45.626	75.301	2	2.1	20 km SW of Ripon, QUE
2007-11-04	16:36:26.0	46.046	74.962	6	2.5	35 km N of Ripon, QUE
2007-11-06	22:47:57.8	43.751	74.987	4	2.3	75 km N of Utica, NY
2007-11-09	09:45:20.9	45.785	75.390	20	2.1	22 km W of Ripon, QUE
2007-11-11	06:03:45.6	46.201	75.223	8	1.7	45 km SE of Mont Laurier, QUE
2007-11-11	15:22:30.6	46.205	75.197	10	2.0	46 km SE of Mont Laurier, QUE
2007-11-15	14:00:35.8	45.543	76.299	7	1.8	49 km W of Ottawa, ONT

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2007-11-18	15:59:46.8	46.176	74.476	15	1.5	56 km NW of St-Jerome, QUE
2007-11-23	17:34:01.8	45.625	74.571	12	1.5	17 km W of Lachutte, QUE
2007-11-23	17:45:29.0	45.626	74.573	12	1.5	18 km W of Lachutte, QUE
2007-11-24	16:29:30.0	45.614	74.567	13	1.9	17 km W of Lachutte, QUE
2007-11-24	18:19:36.5	44.700	74.631	7	2.1	28 km E of Potsdam, NY
2007-11-24	19:32:29.2	45.634	74.578	15	1.3	18 km W of Lachutte, QUE
2007-11-25	19:07:06.5	46.113	75.291	9	2.3	43 km N of Ripon, QUE
2007-11-27	11:42:32.0	44.968	74.785	8	1.4	10 km NE of Massena, NY
2007-12-02	10:32:32.1	45.038	74.039	11	1.5	25 km S of Valleyfield, QUE
2007-12-07	08:48:58.2	45.983	73.602	7	1.7	13 km SW of Joliette, QUE
2007-12-07	11:25:08.6	45.686	74.846	7	2.4	7 km E of Montebello, QUE
2007-12-10	16:01:55.5	46.186	73.119	4	2.6	15 km N of Sorel, QUE
2007-12-12	15:51:20.8	46.299	75.147	15	3.0	40 km SE of Mont Laurier, QUE
2007-12-13	03:29:24.7	42.787	78.205	7	2.6	24 km S of Batavia, NY
2007-12-13	03:33:01.0	42.800	78.196	7	2.0	22 km S of Batavia, NY
2007-12-17	22:11:29.5	46.104	74.902	9	2.5	43 km NE of Ripon, QUE
2007-12-20	12:16:41.4	45.800	76.971	7	3.1	100 km SW of Maniwaki, QUE
2007-12-20	20:20:41.4	46.337	73.557	7	2.1	35 km N of Joliette, QUE
2007-12-23	23:48:35.4	46.172	77.333	24	3.8	108 km W of Maniwaki, QUE
2007-12-28	06:25:20.9	46.390	74.102	14	1.6	64 km NW of Joliette, QUE
2007-12-29	23:05:13.6	45.617	75.256	6	1.4	18 km SW of Ripon, QUE
2008						
2008-01-07	06:13:32.9	42.755	78.181	6	1.8	27 km S of Batavia, NY
2008-01-08	00:00:07.1	43.463	78.154	7	2.0	33 km NW of Brockport, NY
2008-01-09	01:34:47.8	41.740	81.422	7	3.1	15 km W of Painesville, OH
2008-01-10	06:12:43.4	46.106	74.817	17	3.1	46 km NE of Ripon, QUE
2008-01-10	11:36:52.8	44.667	74.571	8	2.3	30 km SW of Malone, NY
2008-01-13	13:01:12.2	45.436	73.505	8	2.0	10 km SE of Montreal, QUE
2008-01-18	11:46:27.9	43.784	78.969	7	1.7	34 km E of Toronto, ONT
2008-01-19	09:19:20.1	43.696	74.103	4	1.8	56 km NW of West Glens Fall, NY
2008-01-20	11:56:01.0	43.202	79.805	7	1.9	62 km W of Niagara Falls, NY
2008-01-20	19:52:45.4	45.600	74.519	9	1.4	14 km SW of Lachutte, QUE
2008-01-26	06:39:01.0	41.800	81.003	9	1.8	20 km SW of Ashtabula, OH
2008-01-27	13:28:21.5	45.918	75.407	7	1.9	29 km NW of Ripon, QUE
2008-01-29	13:57:37.0	45.773	73.460	12	2.4	29 km S of Joliette, QUE
2008-01-30	07:28:06.1	44.460	73.709	7	1.7	34 km SW of Plattsburgh, NY
2008-02-27	07:56:18.5	42.698	74.365	6	2.7	10 km E of Cobleskill, NY
2008-03-06	03:31:35.0	43.528	73.312	10	2.0	29 km W of Rutland, VT
2008-03-07	23:34:47.4	45.289	75.173	7	2.9	44 km E of Ottawa, ONT

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2008-03-08	11:48:44.1	43.030	78.571	6	2.7	17 km NE of Depew, NY
2008-03-09	23:27:07.1	46.361	75.378	10	2.1	24 km SE of Mont Laurier, QUE
2008-03-11	03:10:30.8	41.392	72.505	11	2.4	23 km SE of Middletown, CT
2008-03-14	22:42:31.6	41.336	74.452	3	2.3	13 km S of Middletown, NY
2008-03-14	22:45:37.5	41.321	74.439	5	1.2	14 km S of Middletown, NY
2008-03-14	22:55:52.3	41.318	74.437	5	1.0	14 km S of Middletown, NY
2008-03-15	00:01:14.2	41.313	74.433	5	1.2	15 km S of Middletown, NY
2008-03-15	01:18:44.0	41.337	74.463	7	1.9	13 km S of Middletown, NY
2008-03-15	01:38:09.1	41.317	74.441	5	1.4	15 km S of Middletown, NY
2008-03-15	01:39:25.2	41.320	74.443	5	1.0	14 km S of Middletown, NY
2008-03-15	03:54:15.0	41.292	74.415	5	0.9	17 km S of Middletown, NY
2008-03-15	21:22:22.7	41.289	74.407	5	1.1	18 km S of Middletown, NY
2008-03-18	23:51:31.8	41.346	74.476	1	0.3	12 km S of Middletown, NY
2008-03-20	17:25:45.5	45.035	75.612	6	2.8	39 km N of Ogdensburg, NY
2008-03-23	08:38:57.8	45.770	74.698	9	2.1	20 km N of Hawkesbury, ONT
2008-03-23	10:16:13.3	45.513	75.399	8	1.7	26 km NE of Ottawa, ONT
2008-03-25	04:43:02.8	44.284	76.500	3	2.3	58 km NW of Watertown, NY
2008-03-27	06:27:21.5	41.020	73.372	17	1.8	13 km NW of Fort Salonga, NY
2008-03-29	21:44:56.1	43.867	73.295	5	2.2	19 km SW of Middlebury, VT
2008-03-31	15:47:12.0	45.641	74.822	7	2.6	9 km E of Montebello, QUE
2008-03-31	15:49:06.1	45.628	74.808	6	1.5	11 km SE of Montebello, QUE
2008-03-31	20:45:08.2	45.467	75.829	18	1.5	12 km NW of Ottawa, ONT
2008-04-20	17:44:55.9	45.891	74.290	8	1.4	24 km NW of St-Jerome, QUE
2008-04-22	12:27:25.3	42.655	78.968	8	1.8	23 km SW of Lackawanna, NY
2008-05-06	17:30:23.9	38.806	77.220	6	2.0	11 km W of Alexandria, VA
2008-05-12	06:11:26.4	42.891	78.235	1	2.2	13 km S of Batavia, NY
2008-05-17	08:22:31.2	44.771	74.718	11	1.4	22 km SE of Massena, NY
2008-05-28	22:39:05.1	43.507	73.485	5	2.3	24 km N of Hudson Falls, NY
2008-05-31	19:03:12.4	41.450	79.586	25	2.3	21 km S of Titusville, PA
2008-06-01	01:14:42.9	45.103	73.951	21	2.2	22 km SE of Valleyfield, QUE
2008-06-02	06:21:36.7	45.639	72.620	5	2.5	26 km E of St. Hyacinthe, QUE
2008-06-06	20:50:09.9	45.098	74.774	15	2.2	21 km NE of Massena, NY
2008-06-08	05:04:21.4	44.809	74.895	4	1.3	17 km NE of Potsdam, NY
2008-06-11	04:36:34.5	45.639	75.385	18	3.3	24 km SW of Ripon, QUE
2008-06-25	22:17:48.4	45.094	74.958	10	1.8	19 km N of Massena, NY
2008-06-26	05:42:38.4	45.090	74.972	9	2.3	19 km N of Massena, NY
2008-07-02	10:06:26.3	44.825	74.923	8	1.0	18 km N of Potsdam, NY
2008-07-08	01:43:52.6	45.969	75.182	10	2.1	25 km N of Ripon, QUE
2008-07-15	05:03:25.4	43.814	77.854	5	2.1	67 km N of Brockport, NY

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2008-07-21	01:41:30.9	41.517	80.371	5	2.0	53 km SE of Ashtabula, OH
2008-07-25	00:49:26.0	45.688	74.933	1	1.8	16 km SE of Ripon, QUE
2008-07-26	19:45:31.5	45.452	74.869	17	2.6	25 km S of Montebello, QUE
2008-07-28	15:20:09.5	40.582	75.086	1	2.1	15 km SE of Phillipsburg, NJ
2008-08-02	08:00:29.9	46.094	75.758	5	2.7	35 km SE of Maniwaki, QUE
2008-08-07	10:01:34.6	45.393	73.281	10	2.4	10 km N of ST. Jean, QUE
2008-08-12	05:51:35.7	44.739	75.427	10	1.6	7 km NE of Ogdensburg, NY
2008-08-25	08:05:53.2	46.217	74.829	5	2.3	57 km NE of Ripon, QUE
2008-09-11	08:10:03.4	44.711	74.635	8	2.1	28 km E of Potsdam, NY
2008-09-16	08:25:28.3	44.229	75.952	5	2.0	29 km N of Watertown, NY
2008-09-18	01:04:17.2	41.791	81.435	13	2.2	17 km NW of Painesville, OH
2008-09-19	05:05:51.2	43.943	74.095	9	2.0	43 km S of Saranac Lake, NY
2008-10-02	04:10:24.3	45.215	73.890	2	2.9	20 km E of Valleyfield, QUE
2008-10-03	15:20:44.5	45.754	74.276	23	1.8	13 km NE of Lachutte, QUE
2008-10-05	20:34:48.0	44.971	74.919	8	2.0	5 km NW of Massena, NY
2008-10-05	22:36:48.1	40.054	76.967	2	2.0	15 km NW of Weigelstown, PA
2008-10-07	07:37:07.5	45.912	74.663	6	1.5	34 km NE of Montebello, QUE
2008-10-11	02:47:14.1	46.335	72.547	5	3.0	2 km SE of Trois Rivieres, QUE
2008-10-15	02:12:01.6	45.516	74.058	10	1.6	27 km SE of Lachutte, QUE
2008-10-17	08:02:42.5	44.922	74.692	5	1.5	16 km E of Massena, NY
2008-10-19	08:21:22.7	40.080	77.019	5	1.9	20 km SE of Carlisle, PA
2008-10-19	08:22:07.3	40.092	76.974	5	2.1	18 km S of New Cumberland, PA
2008-10-19	08:26:20.5	40.168	77.038	5	1.2	13 km E of Carlisle, PA
2008-10-19	08:28:09.0	40.087	77.998	5	1.5	19 km SW of New Cumberland, PA
2008-10-19	08:58:31.7	40.092	76.974	4	1.8	17 km SW of New Cumberland, PA
2008-10-19	09:06:01.5	40.091	77.018	5	1.0	19 km SE of Carlisle, PA
2008-10-19	09:08:20.7	40.056	76.962	5	0.8	14 km NW of Weigelstown, PA
2008-10-19	09:08:44.3	40.092	76.987	5	1.1	18 km SW of New Cumberland, PA
2008-10-19	09:17:34.8	40.100	77.009	5	1.7	19 km SE of Carlisle, PA
2008-10-19	09:49:19.1	40.095	77.002	5	1.0	20 km SE of Carlisle, PA
2008-10-19	09:49:51.7	40.076	76.973	5	1.5	19 km SW of New Cumberland, PA
2008-10-19	09:50:11.4	40.091	76.989	5	1.6	18 km SW of New Cumberland, PA
2008-10-20	00:08:26.6	40.159	77.107	5	1.2	8 km SE of Carlisle, PA
2008-10-20	00:14:03.9	40.075	77.005	5	1.1	19 km S of Camp Hill, PA
2008-10-20	02:16:02.4	40.090	76.984	5	1.5	18 km SW of New Cumberland, PA
2008-10-20	08:26:17.8	46.435	75.758	11	3.0	18 km NE of Maniwaki, QUE
2008-10-23	15:55:32.3	40.068	76.962	5	1.2	19 km S of New Cumberland, PA
2008-10-26	13:36:21.7	44.904	73.579	8	1.8	25 km NW of Plattsburgh, NY
2008-11-06	19:12:14.3	41.469	77.367	0	2.0	37 km N of Lock Haven, PA*

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2008-11-07	04:07:03.0	40.097	77.006	1	1.4	20 km SE of Carlisle, PA
2008-11-11	08:12:52.5	45.274	73.000	14	1.5	21 km E of St. Jean, QUE
2008-11-29	11:18:37.6	45.555	75.081	6	1.7	17 km SW of Montebello, QUE
2008-12-15	11:54:17.8	45.653	74.713	17	1.9	17 km E of Montebello, QUE
2008-12-18	06:30:59.9	44.663	75.441	7	1.4	5 km SE of Ogdensburg, NY
2008-12-23	05:02:47.0	43.215	78.874	5	1.5	16 km W of Lockport, NY
2008-12-24	20:59:52.4	45.155	75.553	5	1.3	31 km S of Ottawa, ONT
2008-12-27	05:04:34.6	40.114	76.403	4	3.4	10 km SW of Lititz, PA
2008-12-31	05:34:08.8	40.107	77.003	1	2.1	19 km SE of Carlisle, PA
2008-12-31	06:54:48.7	46.154	75.448	7	3.2	45 km S of Mont Laurier, QUE
2009						
2009-01-06	16:59:12.0	40.300	74.909	0	1.6	17 km NW of Trenton, NJ*
2009-01-09	20:53:00.2	45.748	74.397	10	2.0	11 km N of Lachutte, QUE
2009-01-21	00:12:15.3	44.947	73.777	15	1.7	38 km NW of Plattsburgh, NY
2009-01-26	06:55:28.7	43.254	78.723	7	2.1	10 km N of Lockport, NY
2009-01-30	11:51:55.2	46.227	74.981	5	2.5	54 km N of Ripon, QUE
2009-02-03	03:34:19.0	40.870	74.528	5	3.0	3.5 km W of Rockaway, NJ
2009-02-07	04:08:42.3	44.956	74.789	8	2.3	9 km E of Massena, NY
2009-02-14	22:22:22.8	40.948	74.392	2	2.4	5 km N of Boonton, NJ
2009-02-16	18:17:55.0	40.963	74.389	5	1.1	5 km SW of Kinnelon, NJ
2009-02-16	19:38:31.7	40.948	74.019	7	1.4	2 km SE of Oradell, NJ
2009-02-17	14:33:26.8	42.571	74.135	16	2.1	25 km W of Delmar, NY
2009-02-18	03:41:50.7	42.570	74.103	9	2.7	23 km W of Delmar, NY
2009-02-18	06:42:35.6	40.868	74.551	4	2.3	8 km NW of Morris Plains, NJ
2009-02-18	16:20:23.1	42.572	74.101	10	2.4	23 km W of Delmar, NY
2009-02-19	14:22:58.7	42.573	74.095	8	1.6	22 km W of Delmar, NY
2009-02-20	18:04:19.7	42.573	74.096	8	2.7	22 km W of Delmar, NY
2009-02-21	07:30:43.2	42.569	74.104	11	2.1	23 km W of Delmar, NY
2009-02-23	15:46:20.2	42.574	74.095	7	2.1	22 km W of Delmar, NY
2009-02-23	16:10:02.1	44.884	74.943	10	2.3	6 km SW of Massena, NY
2009-03-02	17:28:19.8	44.358	74.288	7	1.9	13 km W of Saranac Lake, NY
2009-03-05	06:51:05.2	45.615	76.239	5	2.8	48 km NW of Ottawa, ONT
2009-03-10	13:08:25.8	46.045	74.318	12	2.4	37 km NW of St-Jerome, QUE
2009-03-15	16:38:31.7	45.848	75.357	6	2.2	22 km NW of Ripon, QUE
2009-03-22	08:59:10.8	42.627	74.111	15	1.3	21 km W of Westmere, NY
2009-03-22	09:21:01.2	42.634	74.115	16	2.8	21 km W of Westmere, NY
2009-03-22	21:43:27.6	42.626	74.111	15	2.1	21 km W of Westmere, NY
2009-03-24	09:38:20.6	46.095	74.820	10	2.1	45 km NE of Ripon, QUE
2009-04-02	15:32:00.7	42.627	74.117	14	2.2	22 km W of Westmere, NY

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2009-04-03	06:51:48.7	44.902	74.531	13	1.8	20 km W of Malone, NY
2009-04-08	05:02:43.5	42.571	74.099	10	2.3	23 km W of Delmar, NY
2009-04-10	09:45:33.4	45.912	74.014	5	2.3	14 km N of St-Jerome, QUE
2009-04-13	10:08:17.2	42.612	74.134	16	1.8	23 km W of Westmere, NY
2009-04-18	00:43:29.5	44.377	73.795	10	2.2	27 km E of Saranac Lake, NY
2009-04-22	13:21:14.1	40.073	77.002	1	1.1	20 km S of Camp Hill, PA
2009-04-23	22:26:04.4	40.085	76.998	1	2.4	19 km SW of New Cumberland, PA
2009-04-24	05:36:48.8	40.064	77.027	1	2.9	20 km NW of Weigelstown, PA
2009-04-30	22:36:11.3	40.073	77.013	1	2.0	19 km NW of Weigelstown, PA
2009-05-05	06:06:03.9	45.198	73.917	10	1.6	18 km E of Valleyfield, QUE
2009-05-08	19:47:01.5	45.494	75.961	21	3.1	20 km NW of Ottawa, ONT
2009-05-10	14:30:34.1	42.918	77.977	5	2.0	19 km SE of Batavia, NY
2009-05-11	05:18:23.1	40.088	77.001	1	1.3	19 km SW of New Cumberland, PA
2009-05-11	05:34:02.6	40.099	76.970	1	1.2	17 km SW of New Cumberland, PA
2009-05-15	04:10:25.4	45.364	74.744	11	2.0	28 km S of Hawkesbury, ONT
2009-05-18	00:53:29.9	42.571	74.112	9	3.0	24 km W of Delmar, NY
2009-05-18	01:04:24.9	42.571	74.108	10	1.1	23 km W of Delmar, NY
2009-05-18	06:58:14.4	44.557	73.857	10	1.6	33 km NE of Saranac Lake, N
2009-05-18	07:21:57.4	42.567	74.110	6	2.1	24 km W of Delmar, NY
2009-05-19	14:52:32.5	42.574	74.113	14	1.9	24 km W of Delmar, NY
2009-05-20	15:01:06.9	43.112	78.739	2	1.9	20 km NE of Kenmore, NY
2009-05-23	13:02:12.7	45.775	75.004	10	1.6	9 km E of Ripon, QUE
2009-05-24	05:24:00.9	46.233	74.977	5	1.9	55 km SE of Mont Laurier, QUE
2009-05-28	09:19:24.7	45.826	75.826	4	3.0	46 km N of Ottawa, ONT
2009-06-05	15:07:52.7	42.828	78.248	5	2.9	20 km S of Batavia, NY
2009-06-12	00:52:25.3	45.934	74.938	7	1.9	25 km NE of Ripon, QUE
2009-06-18	14:27:34.2	46.307	75.098	6	2.1	42 km SE of Mont Laurier, QUE
2009-06-24	18:42:16.3	46.047	75.260	13	2.2	35 km N of Ripon, QUE
2009-07-01	13:44:43.3	39.644	75.483	5	2.8	14 km S of Wilmington, DE
2009-07-06	11:33:00.0	45.785	74.448	6	2.3	17 km NW of Lachutte, QUE
2009-07-08	10:22:11.4	45.298	73.447	13	2.1	14 km W of ST. Jean, QUE
2009-07-11	03:06:14.6	44.863	75.042	6	2.1	14 km SW of Massena, NY
2009-07-18	01:18:23.2	45.698	73.264	5	2.4	26 km W of ST. Hyacinthe, QUE
2009-07-28	01:14:48.2	44.017	73.564	5	2.0	32 km W of Middlebury, VT
2009-07-31	01:36:59.0	43.407	79.579	6	2.0	35 km S of Toronto, ONT
2009-08-22	07:37:17.4	42.572	74.092	10	1.8	22 km W of Delmar, NY
2009-08-27	01:44:50.3	38.731	71.974	10	2.4	223 km E of Atlantic City, NJ
2009-08-27	06:09:53.7	46.307	74.316	10	2.2	63 km N of ST-Jerome, QUE
2009-08-29	01:34:40.1	45.605	74.624	18	1.7	1 km NE of Hawkesbury, ONT

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Date Year-Mo-Da	Time (hr:mn:ss)	Lat. (°N)	Long. (°W)	h (km)	Mag (Mc)	Location
2009-09-01	00:46:57.5	45.722	75.378	15	2.5	21 km W of Ripon, QUE
2009-09-20	15:09:25.8	43.386	79.440	4	2.6	35 km S of Toronto, ONT
2009-09-23	03:45:59.9	42.825	78.239	5	2.4	20 km S of Batavia, NY
2009-09-26	21:12:20.1	44.930	73.121	10	2.0	37 km SE of Napierville, QUE
2009-09-29	13:58:51.5	39.607	76.342	5	1.6	12 km NE of Fallston, MD
2009-10-09	17:23:08.4	40.143	73.674	7	2.1	30 km E of Belmar, NJ
2009-10-10	21:49:52.1	44.091	75.189	8	2.4	56 km S of Canton, NY
2009-10-12	02:38:47.3	45.507	75.303	6	1.5	31 km SW of Ripon, QUE
2009-10-13	12:46:44.6	44.954	74.781	10	1.8	9 km E of Massena, NY
2009-10-18	17:13:42.5	44.663	73.958	5	2.2	34 km SE of Malone, NY
2009-10-20	19:04:08.7	42.580	74.139	10	1.8	25 km SW of Westmere, NY
2009-10-21	01:32:22.1	42.572	74.103	10	2.0	23 km W of Delmar, NY
2009-10-21	01:32:43.2	42.572	74.104	7	2.9	23 km W of Delmar, NY
2009-10-25	11:16:13.7	40.089	76.998	0	2.6	19 km SW of New Cumberland, PA
2009-10-25	11:18:42.2	40.075	76.987	0	1.8	20 km SW of New Cumberland, PA
2009-10-25	11:21:57.9	40.092	76.999	0	2.8	18 km SW of New Cumberland, PA
2009-11-02	03:16:45.2	46.108	74.753	4	3.6	49 km NE of Ripon, QUE
2009-11-27	04:44:03.4	44.890	73.772	5	2.3	33 km NW of Plattsburgh, NY
2009-12-13	21:10:48.8	42.568	74.108	10	2.6	23 km W of Delmar, NY
2009-12-13	22:00:50.5	42.573	74.108	10	3.1	23 km W of Delmar, NY
2009-12-16	13:17:43.4	45.012	74.467	10	1.8	23 km NW of Malone, NY
2009-12-20	05:36:12.2	40.580	75.191	3	2.3	13 km S of Phillipsburg, NJ
2009-12-21	23:26:31.2	43.425	78.664	8	2.7	28 km N of Lockport, NY
2009-12-26	23:53:13.9	40.878	74.550	6	2.0	8 km NW of Morris Plains, NJ
2010						
2010-01-04	00:20:44.6	44.586	73.846	10	1.8	34 km W of Plattsburgh, NY
2010-01-06	02:20:03.0	42.575	74.187	20	1.2	27 km SE of Cobleskill, NY
2010-01-06	15:28:59.8	44.984	74.186	10	2.0	17 km NE of Malone, NY
2010-01-10	20:00:44.1	45.226	74.023	10	1.8	9 km E of Valleyfield, QUE
2010-01-13	21:36:48.4	45.621	74.909	12	2.7	6 km S of Montebello, QUE
2010-01-14	20:53:54.4	41.471	77.382	0	2.0	38 km N of Lock Haven, PA*
2010-01-15	20:11:15.0	41.463	77.390	0	2.2	36 km N of Lock Haven, PA*
2010-01-17	00:17:38.4	45.139	75.048	12	2.4	26 km NW of Massena, NY
2010-01-20	21:07:04.0	41.462	77.383	0	2.1	37 km N of Lock Haven, PA*

* Mag=Magnitude: Mc = coda duration magnitude determined by LDEO; b = mb(Lg) Nuttli's 1-sec period Lg-wave magnitude reported by NEIC; L = M_L , local Richter magnitude determined and reported by Lamont-Doherty Earth Observatory of Columbia University; n = Nuttli's mb(Lg) reported by Geological Survey of Canada, Ottawa or by the Weston Observatory, Boston College, MA.; w = M_w , moment magnitude from waveform moment tensor inversion; default magnitude is Mc = coda duration magnitude determined by LDEO. Event location denoted by an asterics (*) is a quarry blast.